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[FOURTH SERIES.]

ART. XLIX.—*A Theory to Explain the Stratification of the Electric Discharge in Geissler Tubes;* by H. V. GILL, S. J. (With Plates IV, V.)

IN the following paper it is proposed to put forward as simply as possible certain ideas regarding the cause of the stratifications seen when a discharge of electricity takes place in a Geissler tube, and to describe some experiments which have been made to test the value of these ideas.

The stratified discharge is without doubt the most striking phenomenon presented in the case of an electric discharge through a Geissler tube, and has naturally attracted the attention of many scientists. Though, however, a vast amount of time and trouble has been expended on expensive researches as to the true cause of this curious and beautiful phenomenon, it must be said that no theory has, up to this, been accepted as satisfactory. As the question is one of great interest and importance, any contribution, however small, towards the solution of the mystery is of value, and hence it is deemed advisable to present the following paper.

In the first place, it will be useful to consider the electric spark under normal conditions, especially with reference to such of its mechanical effects as will help to throw some light on the theory we are about to develop, since those who have devoted special attention to this point are all of opinion that the discharge in a rarefied gas is in no way different from the discharge in air under ordinary conditions of pressure.*

* "The striations are only clearly marked within somewhat narrow limits of pressure. But it is in accordance with the conclusion which all who have studied the spark have arrived at—that there is complete continuity between the bright, well-defined spark which occurs at high pressures and the diffused glow which repre-

Since the most usual form of the spark in air is oscillatory, we may therefore conclude that the discharge in a Geissler tube is oscillatory likewise. These oscillations may vary in frequency from hundreds of millions per second, as in the experiments of Hertz, to some hundreds per second as in those of Dr. Lodge. That the oscillatory discharge is the more usual form of a spark appears from the most recent researches. For example, Prof. Trowbridge writes:* "The oscillatory discharge may be said to be the common occurrence in nature in the case of electrical discharges, and the one-direction discharge the uncommon. . . . In general nature avoids an unidirectional discharge."

The stratified discharge may be produced not only by an induction coil and by an electric machine, but also by a battery of elements in series. . . .

That the discharge of such a battery is in no way different from the spark discharge produced by other means, is the conclusion arrived at by physicists.

De la Rue and Müller† made use of a battery containing, when completed, some 14,000 chloride of silver cells; with this battery they performed a long series of experiments which are described at length in their various memoirs presented to the Royal Society. The discharge was found to consist of a number of distinct sparks, when examined in a rotating mirror, making 17 revolutions per second: they add,‡ "When a considerable resistance was added to the circuit, for example 4 megohms, the character of the spark was completely modified. We obtain, at a distance (between a point and a plate) a little less than in the ordinary case, a series more or less rapid of sparks analogous to those of a small Leyden jar, and which pierce the paper by small holes."

In connection with this statement it will be found useful to consult the paper of Prof. Trowbridge just cited, and in which he says: "Since the discharge from an accumulator of a large number of cells is, in general, oscillatory, I am led to the belief that the discharge from any primary battery is also oscillatory, for in all cases we have to deal with capacity and self-induction."

We insist on these facts, as they form the basis of the explanation we are about to propose. For the same reason it is necessary to recall some of the mechanical effects produced in the air by electric sparks. The most familiar of these effects is the

sents the discharge at high exhaustions—to suppose that they always exist in the spark discharge, but that at high pressures they are so close together that the bright and dark parts cease to be separable by the eye." ("Recent Researches," J. J. Thomson, p. 199.) Our investigation will show that at least the *conditions* which give rise to the strata are always present in an electric discharge.

* This Journal, Sept. 1897.

† Phil. Trans., 1878, 1880, 1883.

‡ Phil. Trans., vol. clxix, p. 55.

production of longitudinal wave disturbances, of the same nature exactly as those studied in acoustics. These disturbances have been investigated by several physicists, but with perhaps the greatest success by E. Mach.* We give briefly the results of some of his experiments.

When two sparks were made to take place simultaneously, he proved the laws of interference were fulfilled exactly as in the case of air waves studied in acoustics. The velocity of the wave is at first greater than that of a sound wave, but at some distance from the point of discharge becomes equal to it.† In order to study these interferences he employed a plate of smoked glass, and the sparks took place over its surface. The curve of interference was registered by lines on the glass where the black covering was removed by the waves at their points of interference. For example, one spark took place along a metalized string parallel to the surface of the glass and quite near to it, thus producing a line of sparks between the particles of metal on the string: a second spark passed from a terminal vertically over the plate, forming a spark at a single point. The waves due to the first spark evidently formed a cylindrical surface with the string as axis, while those due to the second formed a spherical surface around the point. The line of interference on the surface of the glass was, as theory demands, a parabola having the point for focus and the line as directrix. The surface of interference could be determined by moving the plate of glass into various positions in space. A wire containing two breaks was placed between two plates; the direct waves interfered with the reflected ones.

In all these cases the lines and surfaces of interference obeyed the laws of longitudinal waves in an elastic medium.

The velocity of the wave was found to increase with the intensity of the discharge. We call special attention to the following remark. He determined by an ingenious method the fraction expressing the density of compression to be $\sigma=0{\cdot}15$. "The experiments of Toepler and Boltzmann give $\sigma=0{,}0035$ for the condensation of a column of air in vibration near a node (in an organ pipe); we see therefore that the condensation in the air waves produced by even feeble sparks is much greater than that observed in sounding pipes."

It follows from these results that if the oscillations of a spark could be rendered sufficiently slow, a musical note ought to be obtained. Dr. Lodge‡ has actually obtained this result, and reduced the frequency of oscillation to 500 per second.

* Vienna Academy, May-July, 1878; Journal de Physique [1], viii.

† It seems more probable that this falling off of the velocity is more apparent than real; we are inclined to think that the greater velocity near the spark is due to local effects such as the electrical state of the air in its vicinity, the movement of the air near the spark, etc.

‡ Modern Views, pp. 376–377.

Toepler* investigated these air disturbances by the 'stroboscopic method' of Plateau, and found that there are periodic expansions and contractions of the air along the line of discharge; these results are illustrated in his paper, which it will be useful to consult in connection with the experiments we are about to describe.

Antalik† and also Quet and Seguin‡ found that powder, such as finely divided carbon, placed on a plate between the terminals arranged itself in ridges at regular intervals along the line of discharge. Joly§ made some interesting experiments of a somewhat similar nature. These experimentalists, however, seem to have attributed the results to purely electrical causes.

The different effects produced by sparks have been imitated by means of hydraulic models, in which currents of water were made to take the place of the electric currents. We read for example:‖ "But the case in which the imitation of stratified light is striking is when one produces currents of liquids or air, interrupted at regular intervals by the vibrations of a tongue at the mouth of the tube by which the jet of water is projected on the layer of powder."

We now pass to the consideration of the stratified discharge in vacuum, in connection with which are three facts on which our theory rests, which will be seen at once to be but logical deductions from the experiments in air just cited.

These facts may be stated as follows:

1st. The discharge which gives rise to stratification is never a continuous one, but is intermittent—and as we have seen is probably oscillatory.

2d. The gas at a stratum is not in the same physical condition as at an obscure place, but is of a quasi-resisting nature.

3d. It follows from the first that the strata are not places of continuous brightness, but are alternately bright and obscure.

That the first exists is proved by the following facts.

Spottiswoode¶ examined the striæ in a rapidly rotating mirror, and noticed that the image of a stratum presented, not a continuous streak of light, but a series of short bright lines separated by dark intervals. His remarks refer to the effect of a *single spark* of his great coil. He states that sometimes the striæ have a general progressive movement, usually from the positive pole. He showed that this apparent movement is

* Pogg. Ann., cxxxiv, p. 194, 1868; see "Recent Researches," J. J. Thomson.
† Id. cliv, p 14, 1875.
‡ Comptes Rendus, xlviii, p. 340, 1859.
§ Proc. Roy. Soc, xlvii. p. 78, 1890.
‖ C. Decharme. Ann. Chim. Phys. (5) lxxix, p. 416, etc., 1883.
¶ Proc. Roy. Soc., xxv, p. 73.

caused by the striæ reappearing successively at places, each a little in advance of the former position: if the striæ always reappear at the same position there is no general movement. Strata which are thus unsteady may be rendered steady by adding resistance to the circuit, which alters the period of oscillation. (See J. J. Thomson, "Discharge of a condenser.")

De la Rue and Müller,* with their battery above referred to, made many experiments on the stratified discharge. With regard to the results of their investigations they say: "... These results therefore confirm the conclusion already arrived at from other experiments, namely, that the discharge in vacuum tubes is intermittent: but we do not pretend that they make it manifest that stratification is *dependent* on intermittance."†

A passage from De la Rive's‡ paper is as follows: "In reality whether we use a coil, a battery of cells, a machine, etc., to produce stratification, we have never a continuous discharge, but a series of discharges which succeed each other so rapidly that the discontinuity cannot be detected even by a galvanometer. But this discontinuity none the less exists, as Mr. Gassiot has shown by using a battery of grove cells at high tension, which, with the same electrodes can give rise at first to stratifications, and later on to an arc when the discharge has become continuous." Wiedemann and Ruhlmann§ arrived at the same conclusion.

Many other passages‖ might be cited, but we think enough has been said to show that no doubt seems to exist as to the discontinuous nature of the stratified discharge.

The second fact, concerning the physical condition of the gas at a stratum, is proved by the following passages.

De la Rue wrote some time after the memoirs referred to were published:¶ "During our experiments we were struck by the evident plasticity of the strata, whose form at times becomes modified when they meet with an obstacle or are influenced by other causes, as for example the crossing of other strata produced by a separate discharge. . . . . A tube with a hydrogen residue gives evidence of this viscosity of a stratum: at right angles is a tube of small diameter; in this tube is a

* Phil. Trans., pt. 1, vol. clxiv, pp. 55–121.

† Cf. also Ann. Chim. Phys. [5], xxiv, p. 461, 1881, where de la Rue refers to the exceedingly great number of "intermissions" per second—"of millions in a second."

‡ Ann. Chim. Phys. [4], viii. 1864.

§ Pogg. Ann., cxlv. p. 235 and p. 364.

‖ Cf. Phil. Trans., clxix, p. 88, in which de la Rue and Müller state that a Varley condenser of 48·8 microfarad capacity was employed with excellent results in the production of the stratified discharge. The discharge of such a condenser is evidently oscillatory.

¶ Nature, xxix, p. 350, 1884.

stopper having a loop underneath from which is suspended by two silk fibres a needle of decarbonized iron. . . . . The needle was now placed at right angles to the tube and the point made positive. After a few trials at different exhausts a beautiful tongue-shaped stratification was obtained and it was then possible by altering the amount of current to make the apex of a stratum impinge on one or other end of the needle: on whichever end the stratum touched that end was pushed away by it, showing clearly that the balance of forces which held together the molecules composing a stratum are sufficient to render it viscous, and unyielding to a small resistance."

De la Rue and Müller* also came to the same conclusion from other experiments that there were vortices in the gas at a stratum.

In a more recent paper† on this subject we read: "Another effect, to which I have before alluded, is the apparent resistance which the sharply-defined edges of the strata offer to the penetration of the wire. The edge acts as if it had an elastic skin, or a sort of surface tension, bending in as the wire pushes against it, and finally snapping back to its original position, leaving the wire well within the luminous disk. Too little is known about the strata to make any discussion of these facts worth while, and I merely record them without comment."‡

Having thus enumerated the chief facts on which our theory rests, it will be seen at once that it is their natural consequence. It may be stated in general terms as follows:

* Nature, Aug., 1883, p. 383

† R. W. Wood, Physical Review, Nov.-Dec., p. 204, 1896.

‡ It may be well to recall some of the conclusions arrived at by de la Rue and Müller (Phil. Trans., vol. clxix, p. 230)

"1°. The discharge in a vacuum tube does not differ essentially from that in air and other gases at ordinary atmospheric pressures: it cannot be considered as a current in the ordinary acceptation of the term, but must be of the nature of a disruptive discharge, the molecules of gas acting as carriers of electrification."

"2°. As the exhaustion proceeds, the potential necessary to cause a current to pass diminishes up to a certain point, whence it again increases, and the strata thicken and diminish in number till a point is reached at which, notwithstanding the high e. m. f. available, no discharge through the residual gas could be obtained."

"3°. All strata have their origin at the positive pole." . . .

"6°. If the discharge is irregular and the strata indistinct, any alteration in the amount of current makes the strata distinct and steady."

"7°. The greatest heat is in the vicinity of the strata." . . .

"11°. At the same pressure and with the same current the diameter of the tube affects the character and closeness of the strata."

In a later memoir (Phil. Trans., pt. I, vol. clxxi, p. 108), they continue:

"1°. For all gases there is a pressure which offers the least resistance to the passage of an electric discharge. After the minimum has been reached the resistance to a discharge rapidly increases as the pressure of the medium decreases." . . .

"3°. When the discharge takes place there is a sudden dilatation of the medium in addition to and distinct from that caused by heat. This dilatation ceases instantly when the discharge ceases." . . .

"6°. The electric arc and the stratified discharge are modifications of the same phenomenon."

The electric discharge which gives rise to the stratified column being discontinuous produces periodic disturbances in the gas; these disturbances are propagated as are sound waves, studied in acoustics—exactly as in the case of Lodge's "musical sparks," if we may use the term. The stratifications are the nodes caused by these waves. In other words, the phenomenon of stratification is a form of Kundt's experiment in which the heaps of powder which accumulate at the nodes are replaced by the strata of molecules between which the discharge is taking place in a luminous form.

This idea was suggested by the similarity of the aspect of a stratified discharge and the arrangement of the powder in Kundt's experiment, together with the fact of the oscillatory nature of the electric spark. In subsequently examining the literature of this question we found that an idea somewhat similar to this had been indicated by more than one physicist,* particularly by De la Rive.

The following are some of the most striking points of resemblance between the stratified discharge and Kundt's experiments:

The appearance of the "concamerations" in Kundt's tube resembles in a striking way a stratified discharge. "In a second series of experiments M. Kundt has perfected his method by replacing the lycopodium powder by silica in very fine powder, obtained by the calcination of gelatinous silica; it forms at the nodes, no larger heaps, but "membranes" stretching across the whole section of the tube."† It is interesting to note that the nodes formed in the case of singing flames when the tube containing the flame is sounding by resonance in unison with an exterior note, have been shown by Schaffgotsh to be visible when a current of smoke ascends the tube. We may mention that de la Rue had noticed this resemblance and reproduced the figure from Tyndall's Sound, but he makes no mention of a similarity of cause.

Sometimes the powder in Kundt's tube takes a spiral form; the same has been at times noticed in a stratified discharge.

The diameter of the tube influences the distances between the nodes in Kundt's tube because it influences the velocity of transmission of the wave motion; the distance between the strata in Geissler's tube is similarly affected.

The general flow studied by Spottiswoode, above referred to, seems to be excellently explained by this theory—an explanation which, however, we propose with every reserve. As has

* Cf. De la Rive, Ann. Chim. Phys. [4], viii. p. 437, 1866. Gassoit. Phil. Trans., 1858–59, etc. Stafen Journal de Physique, ii, p. 190, 1873. Neyreneuf, Comptes Rendus, lxxviii. p. 950, 1874; lxxx, p. 1881, 1875; lxxxii, 1876.

† Cf. Tyndall's "Sound."

been already indicated, this movement is due to the fact that after each extinction, the stratum is renewed at a slight distance from its former position; if the stratum always reappears at the same place, there is no general movement. In Kundt's experiment, if the length of the tube is an exact multiple of the half-wave length of the note, stationary nodes are formed. But if the length is not an exact multiple of the half-wave length the nodes are not stationary, and at each vibration the node is formed a little in advance of its former position; in this case the heaps corresponding to the true nodes, when the length of the tube is a multiple of the half-wave length, are not formed with exactness, but between them are secondary smaller heaps due to this progressive form of the wave. In order to obtain the nodes well defined and without secondary heaps two means may be employed. We may either alter the length of the tube, which is the means employed by Kundt, or we might alter the note so that its half-wave length became an exact fraction of the length of the tube. If, however, we go beyond the necessary alteration a new phase of indistinctness occurs, which could be again remedied by a still further change in the length of the tube or the period of the note. Compare the following facts, bearing in mind that the oscillations are altered by the resistance of the circuit. "When the strata are in motion they preserve their respective distance apart, and their number presents neither diminution or augmentation."* "This flux can be regulated by introducing resistance into the circuit."* "Oftener we can obtain a phase of stability by introducing with care exterior resistances; if we continue to add resistance, the introduction will produce a new phase of instability, and on adding still greater resistance a phase of steadiness."† Here we see a remarkable confirmation of this theory. We must remember that in the case of strata the "note" is very high‡ and consequently a slight change in the note which would produce steadiness would not produce a change in the wave-length sufficiently great to be observed, hence the distance between the nodes will apparently remain the same in both cases. This might also be due to the "damping" effect of a wet thread, etc., especially in the case of an induction coil, for in this case the intensity, etc., of the spark is not constant during its discharge. The damping would get rid of some of the final oscillations which would render the period unsteady.

* Spottiswoode, loc cit.

† de la Rue and Müller, Phil. Trans., Pt. I, vol. lxix. fin.

‡ Although the period of a note must be within certain limits in order that it may be heard as a musical note, yet vibrations having a frequency far beyond this limit can be propagated in air. "Vibrations transmitted as waves through steel or air or water cannot be more frequent than a certain number, which I cannot now put a figure to, but which I say, may be reckoned in hundreds of thousands or a few million per second." (Lord Kelvin, Nature, March 6th, 1884.)

Another proof is afforded by a fact which seems to have met with no explanation. Sometimes it was noticed that the interior of the tube was covered by rings of a dark deposit; these rings have been proved by several to be proper to the dark spaces. For instance, Gassiot* states: "In one of Cetti's tubes originally charged with arseniuretted hydrogen there was such a deposit." . . . "This result (i. e. of experiments which we need not dwell on), appeared to me to explain that the deposit in Geissler tubes did not arise from particles of the negative electrode, but from the gas with which it was originally charged; their being deposited exactly in the dark portions between the luminous disks may lead to a correct explanation of a phenomenon which has hitherto baffled the ingenuity of experimentalists."

Now our theory seems to supply an explanation of this fact. Let us remark that these rings have not been noticed in the case of pure gases such as hydrogen, oxygen, carbonic acid gas, etc. In the case referred to by de la Rue and Müller the nature of the gas is not stated. Probably the latter refer to the same tube as does Gassiot, for they say it was noticed in a tube which had belonged to Gassiot. To proceed, the gas is thrown into a series of stationary waves, giving rise to nodes and loops. At a node the gas is alternately in a state of compression and rarefaction. When the gas is in a state of compression the discharge takes place between the molecules. This produces a luminous ring which is a stratum. Now, although the mean temperature of a stratum as measured by any form of thermometer is but slightly higher† than that at a dark space, there is no doubt but that the heat generated between the molecules is very great. This heat decomposes the AsH_3. Now when the compression changes into a rarefaction part of the gas thus decomposed makes a slight excursion towards the loop or dark space. The As which has been liberated at the strata is condensed on the sides of the tube in this cooler atmosphere and thus forms the rings. In the elaborate experiments of Gassiot, de la Rue, etc., the discharges were very regular, and hence the strata, as appears from several passages in their memoirs, occurred at the same place. So that there is no difficulty in conceiving how the dark rings always coincided with the obscure places. It would be, in fact, a form of Marsh's arsenic test. We do not know if the deposit in such a tube has been subjected to the arsenic test. This would be an interesting research. In Marsh's test, it will be remembered, the arsenic mirror is formed on that part of the tube just beyond the portion which has been heated.

From this last paragraph appears at once how the very

* Report Brit. Assoc. (Sect.), p. 46, 1869.

† Cf. R. W. Wood, Physical Review, Nov.-Dec., 1896.

nature of the discharge tends to augment the forces which cause the nodes. It is only necessary to consider that the heat generated in the discharge between the molecules forming a compression tends at once to augment the effect of rarefaction usually produced by the elastic nature of the gas. Hence the nodes are sustained in an automatic manner arising from the very nature of the discharge.

Again it is much more difficult to decompose the discharge by the rotating mirror when the strata are close together (or as we should say, when the frequency of oscillation is greater); "as the battery surface is still further increased (i. e. current working coil) these diagonal lines (image of an unsteady discharge) appear more and more crowded together, until at last they blend into unbroken flocculent striæ."* Or the mirror was not revolving sufficiently fast to decompose them.

Helmholtz showed that the surface of a wave in a tube is not plane; we have seen that in the case of the strata it is concave to the positive terminal. The dark spaces are only relatively dark.†

It has been often stated that the strata are but accidental in the discharge; and in reality they only occur for a very limited range of pressures. Geissler tubes may be lit up by rubbing them with a cloth, but in this case strata do not seem to be produced. Such tubes may also be used as detectors for Hertz waves, showing that an oscillatory discharge will light them up.

With regard to the fact stated by Trowbridge (loc. cit.), that the flaming discharge prevented him from observing this discontinuity of the current in a Geissler tube, (he makes no mention of the discharge being stratified,) we may refer to a paper by Sir D. Salomons‡ in which he states that a weak discharge is the most favorable for studying the strata: in this case there would be no flaming discharge.

We have tried the effect produced by using a machine in connection with a varying number of Leyden jars. While the distance between the strata does not present any regular change, which may be accounted for by the different intensities, etc., of the spark, one characteristic effect was produced. With one large jar the strata were about $0{\cdot}5^{cm}$ apart: with four jars we were able to produce strata nearly twice as far apart by carefully regulating the charge, etc. This result is of importance as showing the effect of capacity. However, we do not insist on this fact, as it was not always produced on repeating the experiment.

* Spottiswoode, loc. cit.
† de la Rue and Müller, Nature, 1883, p. 383.
‡ Proc. Roy. Soc., 1891, p. 229.

In studying the strata we must bear in mind that the tube is itself a condenser, and must therefore influence the discharge. These seem therefore good grounds for the theory we have proposed. In the experiments we are about to describe we think there will appear a striking confirmation, and proof of the truth of this explanation.

Experiments with vacuum tubes present peculiar difficulty owing to the nature of the phenomenon. Besides, there is the further disadvantage of the necessity of an expensive apparatus. For these reasons we sought for a long time some means that would be at the same time simple and adequate. The obvious way to test the truth of this theory seemed to be to endeavor to repeat Kundt's experiment with a Geissler tube. But against this was the fact that waves in so rarefied a medium would seem to be incapable of producing so marked a mechanical result. Here, again, however, is the fact that the condensations produced by the electric spark are very much more intense than those produced by ordinary sounding instruments. However we eventually adopted this method, and as will appear immediately, with excellent results. Since we argued that the effect in a rarefied gas was the same as that in air under normal conditions, it seemed logical to test the theory from the very foundation. Hence we shall at first deal with some interesting results obtained in air, and proceed gradually to the stratified discharge.

We have already seen that Mach proved electric sparks to produce disturbances in the surrounding atmosphere exactly similar to those produced by sounding bodies, and that Lodge produced musical notes by the waves produced by the oscillations of such sparks. "One sees clearly why one gets a musical note: the noise of the spark is due to the sudden heating of the air." (We might also add the sudden expansion caused by a spark which is due to electrical causes.) "And now if the heat is oscillatory the sound will be oscillatory too, but both will be an octave above the electrical oscillation, if I may so express it, because two heat pulses will accompany every complete electric vibration, the heat production being independent of the direction of the current."

Evidently if we were to replace the vibrating glass rod in Kundt's experiment by an electric spark, we ought to get nodes and consequently heaps of powder in the same manner. Since the frequency of oscillation of a spark is so exceedingly high, these heaps would be very near together.

This then was the first experiment.

A horizontal glass tube almost one meter long was sprinkled throughout its length with lycopodium powder. The two terminals of a small Voss machine were placed about $1{\cdot}0^{cm}$ apart

near one end. After a few sparks had taken place the interior was strikingly divided throughout its whole length into little heaps quite close together. When the tube is looked at from one side, at the moment when the spark passes it is noticed that the powder rises a considerable distance at the heaps and then falls back. When the tube containing the powder is narrow, the lines of powder almost reach to the top. The result surprisingly corresponded with what we had looked for. In order to obtain a permanent record the following simple means was employed: A strip of photographic paper was placed in the tube with a small amount of powder on it. When the sparks had taken place the powder was thrown into position. The whole was then exposed to the daylight: the part occupied by the powder then appeared as white in a black background. Fig. 1, Plate IV, shows a typical example. (This way of obtaining records is very useful, and has succeeded well in the case of other phenomena, such as the magnetic lines of force, as exhibited by iron filings.)

The following are some facts about this experiment.

The greater the intensity of the spark, and the greater the capacity of the condenser, the farther apart are the lines. Thus we obtained a series of results with condensers of varying capacities. This law is well illustrated by the series of photographs.

It did not appear to matter whether the end farther from the spark was open or closed—the spark end was open in every case.

The waves could be reflected from the farther end of the tube into a second tube in which the same result was obtained.

That this result is due to air waves is clear from the researches of Mach. We confirmed it in a simple way. Some lycopodium powder on photo paper was placed in an ordinary straight lamp chimney, one end of which was $2{\cdot}8^{cm}$ in diameter, the other $3{\cdot}6^{cm}$. A piece of paper was stretched tightly over one end and tapped sharply; the vibrations thus produced caused the powder to divide up into heaps a few millimeters apart. As we should expect, these heaps were farther apart when the paper was over the larger end of the tube. In order to assure ourselves that the formation of these heaps was not due to the current of air caused by the spark as distinct from the vibrations, we replaced the paper in the last experiment by a bit of cloth; on tapping the cloth no movement whatever was produced in the powder, as would have been the case had the puff of air caused by tapping the cloth been the cause of the division of the powder into lines.

We have dwelt on this experiment, as we think it has not been made before. We describe also some interesting variations which were probably suggested by the plates in Mr. J.

H. Vincent's* paper on the "Photography of Ripples," and which are striking illustrations of the laws of acoustics.

The first consisted in obtaining the circular rings which correspond to the rings on a lake when a stone is thrown in. In this case the formation of the heaps of powder presents a difficulty, as there does not seem to be any reflection of the wave. For many reasons, however, they would seem to be due to the oscillations of the spark as distinct from the sudden movement of the air caused by the explosion. We have repeated the experiments here described, substituting explosions, caused by a mixture of hydrogen and oxygen, for the spark,—in many cases more intense than those due to spark,—but in no case was the powder divided as when sparks were employed. This seems to prove, that the effect is not due to the mere current of air caused by the explosion. Another time we hope to examine this question with greater detail. A hole was cut in a piece of sensitive paper; lycopodium powder was scattered as evenly as possible all round. The two terminals were arranged so as to allow a spark about 1^{cm} long to pass vertically through the hole in the paper. The waves caused by the oscillations will of course be circles concentric with the spark. Fig. 4, Plate IV, shows the result. It will be noticed that the rings are nearer together some distance from the spark than near to it. There is an area round the spark from which the powder has entirely disappeared. This is due not only to the violence of the spark explosion, but also to the fact that a considerable portion of the powder is attracted by, and adheres to, the discharging terminal. Could not this throw some light on the 'negative dark space' in vacuum discharges? The only difficulty in obtaining this and the following results is in distributing the powder evenly over the surface at the beginning. Another point of importance is that the terminals should stand quite vertically, and not pass near the surface of the paper, as the powder in this case is attracted by them.

The effect due to reflection is well shown in Fig. 5, Plate V. In this case the "mirror" was a piece of thin metal about $1{\cdot}5^{cm}$ high placed on the surface of the paper. The spark passed at some distance, as is evident from the photograph. The caustic appears very clearly defined, and the focus is quite distinct.

The interference of the air waves due to two simultaneous sparks was also investigated in the same way. In this case the lines of interference were well marked and formed a hyperbola with the two sparks as foci.

In all these photographs it is noticeable that the lines are farther apart near the spark than at some distance. This

* Phil. Mag., June, 1897.

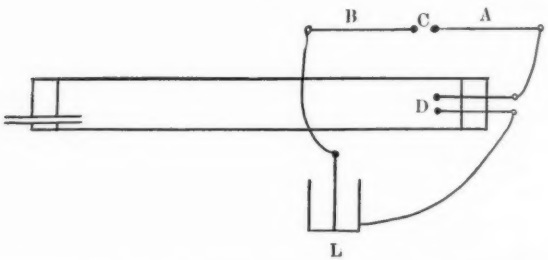
agrees with the statement by Mach that the velocity of the wave is greater near the spark than at some distance from it (see above).*

Many other interesting developments might be made, but enough has been said to show the reality of the air waves, and to give some idea of their dimensions. Whether this result could be used to determine exactly the period of oscillation of a spark is a point outside the scope of the present article. In Kundt's experiment the period of the note is calculated from the formula $v = n\lambda$ where v = the velocity of sound, and λ the wave length, i.e., twice the distance between two consecutive heaps of powder. In experiments with sparks the waves are not propagated with the velocity of ordinary sound waves; again, the intensity of the spark has so considerable an effect on the distance between the heaps that measurements derived from these distances would not be of much value. An induction coil produces similar results, but not nearly so well marked as does the Voss machine.

Having thus established that electric sparks can produce, in air under ordinary conditions of pressure, the effects among which we place the stratification in Geissler tubes, let us examine the result produced when the spark takes place in a vacuum.

As gases at low pressures—within certain limits—are good conductors of electricity, it is not quite so easy to produce intense sparks in a vacuum as in the air. This difficulty is got over by arranging the apparatus as in Fig. 6. When A and B,

6.



the terminals of the machine, are at a suitable distance apart, sparks take place simultaneously at C and D. Of course we could simply charge a Leyden jar and then discharge it, but this operation is troublesome. The pressure of the gas was about 10^{mm}. A few sparks were passed: the powder arranged itself exactly as in our former experiments. Fig. 2, Plate IV,

*Cf. Lord Rayleigh, "Sound." The air waves (sound) produced by very violent causes, such as explosions, travel much faster than "ordinary" sound waves.

shows the result of this experiment. It will be noticed that these heaps are farther apart than when the gas was at atmospheric pressure, but the distance between them is more or less constant. This result is satisfactory in showing that the air waves even in so rare a medium possess considerable force.

The apparatus was now arranged exactly as in the case of a Geissler tube, Fig. 7. After a few sparks the powder was as before thrown into heaps. Fig. 3, Plate IV, exhibits a result for a pressure of 5 or 6^{mm}. These heaps are far apart, which shows the violence of the spark and the great velocity of the waves. This pressure was not sufficiently low to show strata; but it was found that a Geissler tube, when substituted for the tubes used in the last two cases, showed good stratification when the spark passed through it simultaneously with the spark at C.

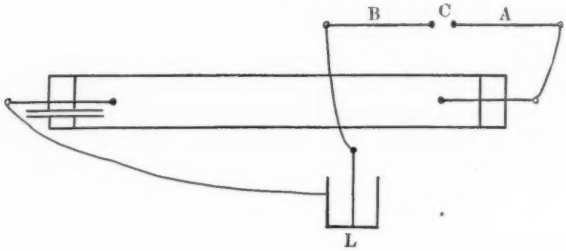
When an induction coil was used the discharge was not sufficiently strong to produce so marked an effect, but at each spark a slight movement in the powder was observed; and when fine powder was used rings were sometimes formed on the sides of the tube.

These experiments prove that when the pressure is not too low and when the spark is of sufficient strength (when the spark is very intense the powder is projected in a heap midway between the two poles), that there exist air waves capable of producing the Kundt's tube effect. From this we may conclude at once that in the case of a Geissler tube these waves likewise exist. It would appear to be conclusively proved that the strata and the formation of the heaps of powder are due to the same cause were we to obtain the Kundt tube effect simultaneously with the stratified discharge, but this was impossible for the following reasons. As we have seen by experiments already cited, and from our own observation, if the discharge is strong its great brightness makes it impossible to observe any stratification; while a strong discharge is essential to produce the heaps of powder. Thus though it is clear that the nature of the spark is the same in a feeble discharge as in an intense one, yet the accidental conditions are such that the discharge favorable for producing the strata is unfavorable for producing the Kundt effect, and vice versa. But if with a strong discharge in a tube containing a gas at a pressure favorable to stratification (with a feeble spark) we obtain the heaps of powder as before described, it seems sufficiently evident that the causes at work in the case of a feeble discharge are the same, and that though insufficiently strong to displace the powder they are quite marked enough to form the waves of gaseous matter, which are the strata.

In order to avoid the trouble of constantly exhausting a tube we had a Geissler tube made containing the purest and finest

lycopodium powder. This tube was 30^{cm} long. One terminal being at the extremity, the other was situated 10^{cm} from the other end. The tube was thus constructed in order to ascertain if the mechanical effects to which we attributed the stratification took place not only between the terminals but also, as our theory demands, in the space which is not between them. This tube was connected as shown in fig. 7, L being a large

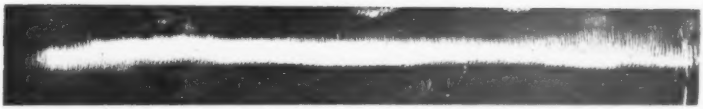
7.



Leyden jar, A and B the discharging terminals of the Voss machine. By placing A and B at a suitable distance apart sparks took place simultaneously at C and through the tube. When A and B were 1^{mm} or so apart frequent sparks took place, the space in the tube being stratified; but these sparks being very feeble, the powder, which had been arranged in a continuous line throughout the whole length of the tube, was not seen to be affected. We see at once from this experiment that the spark in the Geissler tube is oscillatory, for evidently, since the tube and the spark gap are in the same circuit, the nature of the spark is the same at both points: but it has the characteristics of an oscillatory discharge in the gap, therefore it is oscillatory in the tube also. We confirmed this by placing a card covered with lycopodium powder at a spark gap in the circuit, including a Geissler tube showing stratification. The powder was affected as in the experiments already described. Now A and B were 1·5^{cm} apart: at intervals of 10 or 20 seconds intense sparks took place between A and B, the discharge in the tube being exceedingly brilliant. After perhaps a dozen such sparks the powder was definitely arranged. As the sensitive paper was necessarily *outside* the tube the photographic record was very indistinct, but the heaps in the tube were seen to be exceedingly well defined. As some of the powder adhered to the tube the heaps were not well defined in the photograph, which is not reproduced here.

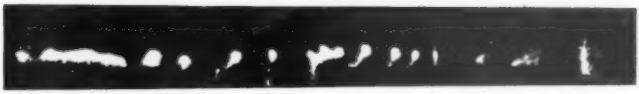
Here it was noticed that the heaps of powder took place, not only between the terminals, but also outside the line of dis-

1.



2.

3.



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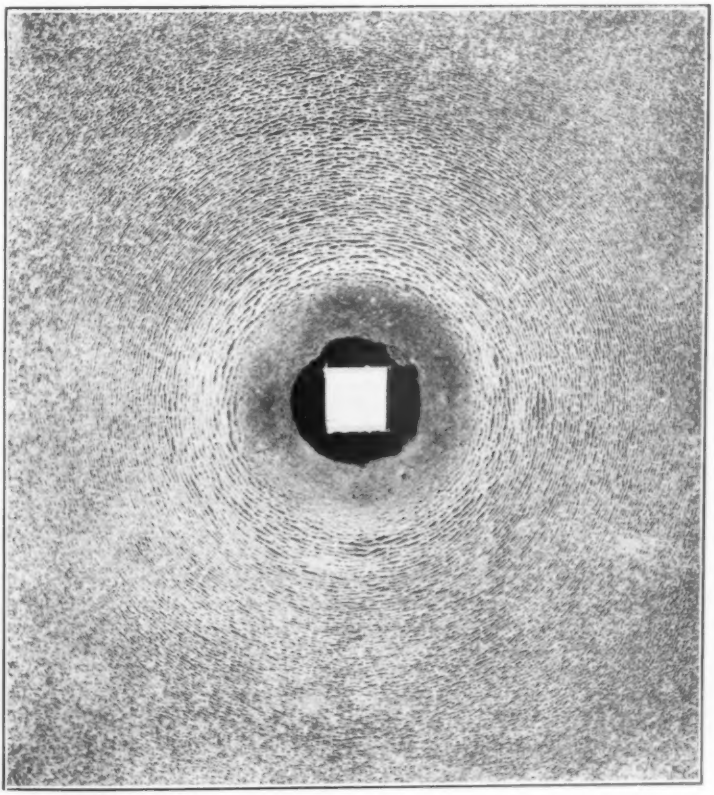
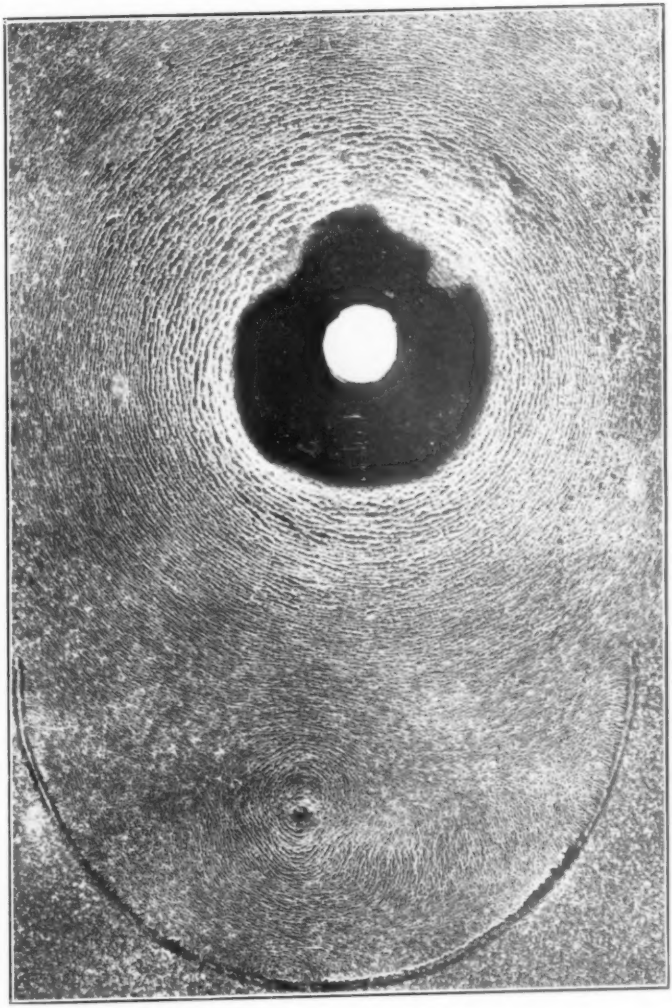


5.



charge, as we had anticipated. Near the negative terminal the lines became indistinct and often were not observed at all. It is not necessary to dwell on the results, as they are sufficiently explained by what has already been said regarding the nature of the spark.

Having proved that there are gas waves in the Geissler tube, we can deduce the existence of the stratified discharge. Since the gas is strongly electrified the discharge takes place between the molecules (or as some hold, between the atoms); these intermolecular discharges produce the illumination in the body of the gas. Add now the effect of waves in the gas. The gas at a condensation will be in a different condition from that at a rarefaction. When the molecules are crowded together at a condensation the number of inter-molecular discharges will be very much greater than at a rarefaction. There will hence be a greater illumination at a node—this is a stratum; but as the state of condensation at a node is intermittent the illumination will be so too. Therefore, remembering that the strata are only relatively bright, and that they are not places of constant brightness, we at once deduce their existence from the presence of the waves caused by the electric discharge. And as this visible effect would only be evident under special circumstances we see how they are only observed within certain limits of pressure, the cause being always present. Thus the identity of the stratified discharge with the ordinary spark discharge seems to be established.

As has been proved by our experiments, the waves in the gas ought to exist all along the tube, even near the negative terminal; their absence as strata being due to mere local influence of the negative pole. In connection with this an experiment of De la Rive's is of interest. Referring to the effect of introducing a small amount of gas into the tube during the stratified discharge, he says:* "We begin by reducing the pressure to 2^{mm} so that the phenomenon of stratification may be as pronounced as possible. We then cause a small amount of hydrogen to enter the tube; if the gas enters at the end near the negative electrode, we see at once strata formed in the obscure space which are of a beautiful rose colour. . . . They are propagated gradually in the tube and unite with the original strata; . . . on arresting the introduction of the gas we see the luminous column slowly leave the negative electrode and take by degrees its primitive appearance." This tends to show that the dark space is due to the comparative absence of gas near the negative electrode, just as in our first experiments in air the powder is driven away near the spark. Both facts are thus probably due to the same cause.

* Loc. cit. p. 451.

It may be of interest to note an effect produced on the powder during the "sensitive discharge." As has been shown by Spottiswoode and Moulton,* in order to produce the sensitive state it is only necessary to put a small spark gap in the circuit. The tube already described was connected with an induction coil, a small spark gap being introduced at the extremity. The powder was distributed evenly all along the tube. When the spark gap was at the positive pole the discharge was sensitive; on touching the tube with the finger the powder inside the tube was observed to (if we may use the expression) boil up, little craters being produced in it at the point touched, as if there were a discharge taking place from the sides of the tube through the layer of powder. No distribution into lines was observed. Near the extremity with the gap the powder was not affected. When the spark gap was at the negative terminal the effect was hardly observable at all; but if the poles were suddenly reversed, on touching the tube the powder was affected. This effect was also noticed on touching the tube after the discharge had ceased. For some days after, the powder in the tube adhered to the side so that it could not be removed by tapping the tube; after some time, however, it became somewhat detached. This effect on the powder was *only* produced when there was a spark gap, and *never* in other cases. These results confirm the explanation which has been given, and we simply mention them in passing.

Such is the theory we propose in order to explain the stratified discharge in Geissler tubes. We have endeavored to express it as simply as possible without at the same time insisting too much on details. Our experiments seem to confirm the hypothesis on which we started, and we see that our results lead back naturally to this starting point. Again, we think any one repeating these experiments will agree that they show the oscillatory nature of the discharge in a vacuum tube.

These experiments might be confirmed by several others which would present but little difficulty to one having at his disposition sufficient apparatus. For instance, Spottiswoode's experiment might be repeated with greater care. Since any system of longitudinal waves can only be propagated by means of rarefactions and condensations, it would follow that two consecutive strata would be in opposite phases. Now we have seen that when the strata are examined in a rapidly rotating mirror, the image of each stratum presents a series of short detached lines. If two strata are in opposite phases it follows that the bright lines composing the image of one stratum should correspond to the spaces separating the bright lines of the next stratum, which spaces should correspond to the bright lines of

* Phil. Trans., 1879–80.

the third stratum, and so on. In the case of an induction coil, the whole series is that due to a *single spark*. The figure in Spottiswoode's paper does not indicate this difference of phase, but it is improbable that he looked for such a result, and, as it might not prove to be sufficiently marked to attract attention when it was not looked for, this is not surprising. Indeed, many reasons might be given to show that there would be a certain overlapping of the different images corresponding to a node.

Again, several interesting results might be obtained by comparing the number of intermissions or oscillations as determined by the mirror, with the distance between the strata, since from this theory it would follow that, *ceteris paribus*, the distance between the strata ought to increase as the frequency of oscillation decreased. However, such experiments might not be conclusive, as this distance would depend, in perhaps a greater degree, on the intensity of the discharge. We were unfortunately unable to compare the period of oscillation as calculated from the formula $v = n\lambda$, with that directly observed by means of a rapidly rotating mirror.

There are, of course, many points to be examined, but as the stratified discharge has received but little attention from the point of view proposed in the foregoing pages, it would perhaps be premature to enter into minute details. On a future occasion we hope to describe some confirmatory experiments which it is our intention to undertake.

Louvain.

Art. L.—*Orthoclase as gangue mineral in a fissure vein;* by Waldemar Lindgren.

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The occurrence of feldspars as gangue minerals in fissure veins is not common. But on the other hand many well-authenticated instances make it certain that they may be formed during the conditions attendant upon the deposition of ordinary fissure veins, i. e. by aqueous deposition. *Lime feldspars* or *soda lime feldspars* appear to occur very rarely, the only known instance being that described by the author from Grass Valley, Cal.* Even this case could not be as completely demonstrated as would have been desirable. *Albite* is more common. While it is only rarely mentioned from European mineral deposits, it has been described as occurring in places very abundantly in Australian gold quartz mines† as well as in similar veins in the province of Minas Geraes, Brazil. In the United States, albite has been noted from several places. Genth describes it from the Steele mine, North Carolina, in the Appalachian gold belt. In California it was first noted by Genth in 1859 from Winters gold vein, Calaveras County.‡

Albite was also described by Wendell Jackson from Stanislaus mine, Calaveras County, and lately again by H. W. Turner from the Shaw mine, El Dorado County. The mineral will probably be found in many other places in the vicinity of the mother lode. It was recently noted by the author in specimens from the Gentle Annie mine, near Placerville. In spite of very careful search no albite has yet been recognized from Nevada City or Grass Valley.

Orthoclase has been described from several European ore deposits, generally having the crystallographic forms and characteristics of adularia. Thus, we find it recorded§ from Schmiedeberg and Kupferberg in Silesia, Himmelfahrt mine near Freiberg in Saxony, Schlaggenwald in Bohemia, Felsöbanya and Schemnitz in Hungary. Also from Transylvania at Botesbanya, Cseb, and Veröspatak. Most of the occurrences in the latter two countries are from gold quartz veins. Everywhere, however, the orthoclase is more of a mineralogical rarity than an abundant gangue mineral.

Breithaupt described, without detailed notes as to its occurrence, an orthoclase of adularia habit from the Valenciana

* 17th Ann. Rept., U. S. G. S., p. 87. This feldspar occurs on small stringers differing in character from the typical gold quartz veins from that locality.

† G. Ulrich, Min. Vict., 1866.

‡ G. F. Becker, 16th Ann. Rept. U. S. G. S., Part 3, p. 278.

§ Hintze, Handbuch der Mineralogie, p. 1361.

silver mine, Mexico, and gave it on account of supposed abnormal angles the name of *valencianite*. This valencianite probably occurred as gangue mineral in a vein.

From the United States orthoclase has been noted by Genth as occurring in minute crystals at the Silver Hill and Steele mines, N. C. G. F. Becker has recently recognized the presence of small grains of orthoclase in a vein quartz from Alaska. It may be added that during the examination of certain auriferous veins at Silver Crown, Wyoming, by the author, grains of microline were sometimes found in thin sections of vein quartz.

Orthoclase is frequently mentioned from tin veins, in Saxony, Bohemia and Cornwall, and while many of these occurrences are beyond doubt, yet it may be pointed out that owing to the peculiar structure of these veins, some feldspar from the surrounding granite might in the older reports have been mistaken for true gangue mineral. While orthoclase of course is common on pegmatite veins, it has not as yet been proved that these ever are auriferous.

During the examination of Silver City mining district, in southern Idaho, undertaken last summer for the U. S. Geological Survey, a vein was encountered which from various standpoints proved to be most interesting.

The Black Jack-Trade Dollar vein outcrops on Florida mountain near Silver City and can be traced for about one mile. The strike of the vein is easterly and westerly; its dip is nearly vertical. It cuts three formations: a normal muscovite-granite forming the fundamental rock, a basalt resting on this granite and a rhyolite, capping both. As the latter two rocks are of Tertiary (Miocene) age the deposit is clearly of comparatively recent origin.

The ore minerals are pyrite, chalcopyrite and argentite; the value is chiefly in silver with a smaller amount of gold. The vein is a characteristic fissure vein, well defined and having a thickness of from a few inches to two or three feet. In the granite it is closely followed by a basaltic dike. The ordinary ore consists of typical vein *filling*, though low grade ores consisting of altered rhyolite appear along certain parts of the vein. The gangue is of an interesting and unusual character, consisting of quartz and orthoclase, in varying proportions. In general, quartz predominates, but at many places the two minerals occur in equal proportions or even with prevailing orthoclase.

The first and most common occurrence of the orthoclase is as large, irregular milkwhite grains, intergrown with vein quartz; it contains inclusions of pyrite and argentite and sometimes thin lamellæ of pyrite deposited parallel to the best cleavage plane. The grains appear under the microscope as

simple crystals. Crusts with projecting crystals of clear quartz and whitish feldspars with broken or curved faces often occur.

The second mode of occurrence is as small, more or less perfect, almost transparent crystals 1–3^{mm} in diameter, coating cracks and crevices in the altered granite adjoining the vein.

The third occurrence is as abundant small and perfect crystals coating a lamellar quartz, itself a pseudomorph after some other mineral, probably calcite.

The vein is apparently richest in orthoclase where traversing the granite. Much of it was also found where it cuts the rhyolite, but none was observed in the basalt. The vein where entering the basalt contracts and becomes very narrow.

All these occurrences demonstrate beyond doubt the aqueous origin of the mineral. The crystals have the habit of adularia, though the only strongly developed faces are 110 and $\bar{1}01$ (*m* and *x*, Dana), producing a distinctly wedge-shaped appearance. One of the larger crystals from the first described occurrence on the main vein was analyzed by Dr. W. F. Hillebrand with the following result:

SiO_2	66·28
Al_2O_3	17·93
K_2O	15·12
Na_2O	·25
Undetermined	·42
	100·00

Specific gravity, 2·54.

The analysis indicates typical adularia. No orthoclase has thus far been found in the other veins near Silver City; many of them, though, possess interesting structural and mineralogical characteristics which will be described in the full report of the district.

Orthoclase has been artificially produced by the wet way by Friedel and Sarasin in 1881. In 1890, Ch. and G. Friedel obtained orthoclase in small crystals by heating pulverized muscovite with a solution of potassic silicate. It is easily seen that the interesting experiment has a direct bearing on this occurrence.

The reason why orthoclase is not more frequently found on mineral veins may possibly be found in the abundant and usual presence of carbon dioxide in thermal waters. Under such conditions the more stable compound—muscovite or sericite—would be formed, orthoclase being rapidly attacked by waters under pressure containing CO_2. Orthoclase could then only result if CO_2 were absent or present in only small quantities.

Stanford University, California, March, 1898.

Art. LI.—*Notes on Rocks and Minerals from California;* by H. W. Turner.

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1. *A Peculiar Quartz-amphibole-Diorite.*

In the northwest portion of the Bidwell Bar Quadrangle on the dividing ridge between Butte and Plumas Counties, is a dike-like streak of a peculiar grayish green rock about 1·2 klm. in length. The exact locality is by the trail to North Valley about 7·3 kilometers south of Table Mountain. The surrounding rock of the district is a granodiorite (granite-diorite) having a composition intermediate between typical quartz-diorite and amphibole-granite. On account of the decomposed condition of the surface rock the exact contact between the supposed dike rock and the granodiorite was not seen, so that its dike nature was not determined with certainty. However, the chemical and mineral composition of the diorite is so different from that of the granitoid rocks surrounding it that its dike nature is regarded as probable.

Two specimens (Nos. 817 and 780 S. N.) of this rock were collected, about 400 meters apart. A microscopic investigation of thin sections of the two specimens shows them to be very similar. The rock is medium-grained and of granolitic texture. It is composed principally of amphibole, plagioclase and quartz. The most abundant constituent, amphibole, is green in color and occurs chiefly in the form of short needles which show idiomorphic outlines in sections transverse to the prism. The amphibole is clearly original, and is imbedded in later feldspar and quartz, both of which are also clearly original. An analysis of No. 817 by Dr. Hillebrand (see below) shows an unusually high percentage of magnesia (11·86 per cent) for a diorite. Since the rock is composed chiefly of quartz, plagioclase and amphibole, it is evident that the magnesia is chiefly in the amphibole, and as much of the alumina (12·9 per cent) must be in the feldspar it was surmised* that the amphibole was rich in magnesia and low in alumina, possibly approximating actinolite in composition. The rather high content of lime (7·74 per cent) was also suggestive of a amphibole rich in lime, since the plagioclase appears to be andesine, a feldspar containing only a medium amount of lime. The amphibole was therefore separated from the rock by means of the Thoulet solution. An analysis made by Mr. William Valentine is given below. There is too much alumina (8·13 per cent) for actinolite. The amphibole may be considered as belonging to the aluminous series. The large extinction angle (23°) likewise places it in the aluminous series.

* Seventeenth Annual Report, U. S. Geological Survey, Part I, pp. 574–575.

Petrographic description of the diorite.—Megascopically the diorite is a grayish-green medium-grained rock showing very abundant short needle-like prisms of a green mineral. Microscopically the rock has a granolitic texture. It is composed of amphibole $>$ feldspar $\overline{>}$ quartz. The accessory minerals are rutile in irregular brownish red grains, apatite in minute prisms, occasional grains of magnetite and possibly a few zircons. Epidote, chlorite and sericite are present as secondary products.

The most abundant constituent, the amphibole, is grayish-green in color and occurs chiefly in the form of short needles which show idiomorphic outlines in sections transverse to the prism. The amphibole is clearly embedded in the feldspar and quartz and therefore earlier. The absorption is $\mathfrak{c}>\mathfrak{b}>\mathfrak{a}$. $\mathfrak{c}$ is brownish-green, $\mathfrak{b}$ green and $\mathfrak{a}$ very light green. The maximum value of the extinction angle $\mathfrak{c}$ on c is 23° as determined by measurements on 55 needles. The feldspar in part shows twinning on the albite law with rather low symmetrical extinction angles on 010 in the few grains measured, suggesting oligoclase or andesine. The feldspar is partly quite fresh but some of it contains minute brightly polarizing fibers, probably sericite. The quartz is fresh and clear and like the feldspar, undoubtedly primary. The chlorite is supposed to be an alteration product of the amphibole. It is green in color and very noticeably pleochroic. The fibers are grouped in rosettes showing olive-gray interference colors. For the purpose of making a separation of the constituents of the rock 48 grams of the powdered rock were passed through a wire sieve with spaces 100th of an inch in diameter. The fine dust and the larger part of the light material (chiefly feldspar and quartz) was washed off with water in a batea. The remainder was put in a Thoulet solution of maximum specific gravity (about 3·18?) only a small amount of the material being precipitated. This was separated and found to weigh about 0·35 grams. A magnet was passed over this powder and a few grains of magnetite extracted. This heavy powder as seen under the microscope is made up chiefly of brownish-red grains presumably rutile, clear grains supposed to be zircon and grains of epidote. A portion of this heavy material was ground up in an agate mortar and treated with $KHSO_4$ before the blowpipe. The bead was dropped in hydrogen peroxide, giving the orange-yellow color characteristic of titanium. The brownish-red grains pretty certainly afforded the titanium, as epidote and zircon were the only other minerals in the powder. Some of the grains are striated. The brownish-red grains are therefore probably rutile. A small quantity of this heavy powder was placed in HF and H_2SO_4 mixed in a platinum dish and digested in a water-bath over night. All of the material was attacked by

the acid except the rutile and zircon-like grains. The rutile is the most abundant of the accessory constituents of the rock. The next heaviest material was of a dark green color and composed chiefly of amphibole. This was removed from the separator, washed and dried and then put into another separator and further purified. An examination of the powder under the microscope showed only an occasional grain of foreign material, so that the chemical analysis of this amphibole may be taken as being very near its actual composition.

Analysis of peculiar quartz-amphibole-diorite.

	817 S. N. Quartz diorite.	817 S. N. amphibole.
SiO_2	54·64	50·08
TiO_2	·61	·76
Al_2O_3	12·09	8·13
Fe_2O_3	1·81	2·69
FeO	5·03	6·71
MnO	0·13	0·49
NiO	0·05	
CaO	7·74	11·21
SrO	*trace*	*none*
BaO	0·05	
MgO	11·86	16·31
K_2O	1·01	0·46
Na_2O	2·35	1·22
Li_2O	*trace*	
H_2O below 110° C.	0·12	*none*
H_2O above 110° C.	2·44	1·40
P_2O_5	*trace*	
CO_2	*none*	
F	*undet.*	*undet.*
Total	100·01	99·46
Analyst	*Hillebrand.*	*Valentine.*

2. *A New Amphibole-pyroxene Rock from Mariposa County, California.*

The amphibole-pyroxene rock to be described occurs in small masses, pretty certainly intrusions, in the slates of the Calaveras formation in the Sonora quadrangle, California. The rocks were first collected by the writer about 1887, but they were not investigated till 1895. The first published notice of this rock may be found in the 17th Annual Report, U. S. G. S., Part I, p. 670. This consists of a note by Dr. F. L. Ransome stating the general character of the rock.

The rock consists of original augite and original amphibole in grains of nearly equal size, with a little quartz and some pyrrhotite. Scattered abundantly through the rock are large phenocrysts of brown amphibole which contain in a poikilitic

manner inclusions of augite and pyrrhotite and occasional crystals of the same primary brown amphibole that occurs in the groundmass. Both the pyroxene and the amphibole grains found in the amphibole phenocrysts are distinct inclusions, with sharp contacts and with diverse orientation and cleavage. The pyrrhotite appears to be original, as the amphibole about it is not in the least altered. Some of the pyrrhotite was separated by using a magnet on the powdered rock and tested with HCl, giving off fumes of sulphureted hydrogen. The amphibole of the groundmass in some cases shows sharp idiomorphic outlines, and there is no evidence that it results from the alteration of augite.

Prof. G. H. Williams has described a somewhat similar rock in this Journal (vol. xxxi, 1886, p. 40). Williams's rock is largely made up of diallage with a little hypersthene and olivine forming a groundmass in which are imbedded large idiomorphic poikilitic amphiboles containing abundant grains of the groundmass. The chief difference between the rock here noted and Williams's rock is the complete absence of hypersthene and olivine and the presence of primary amphibole in the groundmass and among the inclusions in the large amphiboles.

This rock is one type of a very interesting series of basic igneous rocks which are found in the foothills of Mariposa County. Typical gabbros and diabases both with and without olivine and amphibole-picrites represent different types of these igneous rocks. They have not as yet been carefully investigated.

3. *A Quartz-alunite Rock.**

Southwest of Indian Gulch in Mariposa County, California, are three sharp buttes known as the Tres Cerritos. The original material of these buttes appears to have been chiefly meta-augite-andesite tuffs (augite-porphyrite tuffs) and clay slate. The Tres Cerritos lie immediately east of a considerable area of clay slates which are pretty certainly of Jurassic age. They are supposed to belong to the Mariposa formation. Not far west of the buttes by the road to Merced these slates have been metamorphosed into typical chiastolite-schists by a granitic rock.

The rocks of the Tres Cerritos have been subjected to solfataric action and their angular outline is due to the hardness of the altered rocks. The larger portion of these metamorphosed rocks are light brown in color, highly siliceous, resembling quartzite megascopically.

The southeast butte, which was examined with the most care, is composed chiefly of a greenstone-schist which is a

* 17th Annual Report, U. S. Geological Survey, Part I, p. 685.

dynamo-metamorphic form of the meta-augite-andesite tuff. This contains layers of vein quartz, associated with which is pyrophyllite in considerable masses crystallized in beautiful stellate forms. The much decomposed and rusty schists in the creek at the west base of the butte strike about 60° west of north, and dip at an angle of 80°. At one point about due west of the butte the schists are covered with an efflorescence. Some of this was collected and examined by Dr. H. N. Stokes in the laboratory of the U. S. Geological Survey, who reported that the efflorescence is composed of hydrated sodium and magnesium sulphates with a little chloride. In the interior of this efflorescence are grains of calcium sulphate.

The quartzite-like rock under the microscope is seen to be made up chiefly of grains of quartz and a positive uniaxial mineral of greater relief than the quartz, extinguishing parallel to the cleavage and having bright interference colors. Dr. Hillebrand made a chemical examination of this rock and came to the conclusion that the unknown mineral might be alunite.

Chemical Analysis of Alunite No. 870 S. N.

SiO_2	2·64
TiO_2	·40
Al_2O_3	38·05
Fe_2O_3	·23
FeO	Not looked for
MnO	None
CaO	·55
BaO	Not looked for
MgO	trace
K_2O	4·48
Na_2O	2·78
P_2O_5	trace
CO_2	none
H_2O 100°−	none
H_2O 100°+	11·92
SO_3	38·50
	99·55

To make this more certain a quantity of the rock was powdered and the alunite-like mineral separated by means of the Thoulet solution. The specific gravity of the mineral is 2·78 as determined with the Westphal balance by grains suspended in Thoulet solution. Some of the material was heavier than this, but this greater specific gravity was undoubtedly due to inclusions of a brownish red mineral in minute grains without crystal outlines. These grains are too minute for satisfactory determination with the microscope, but a quantitative test of some that were separated from the rock, made by Mr. William Valentine, show that the mineral is rich in titanium. The mineral does not resemble titanite in color, at least such titanite

as ordinarily is found in granitic rocks. It may be brookite, but as before noted, occurs in somewhat rounded forms and not in the small tabular crystals said to be characteristic of brookite. Possibly the mineral is rutile.

On p. 425 is given an analysis of the alunite by Mr. William Valentine. It is probable that the titanic oxide in this analysis was obtained from some of the minute grains of the titanium mineral above noted. As the material was sensibly pure the analysis may be regarded as representing its composition after deducting the titanic oxide.

Alunite has not been previously found in California so far as known.

4. *Zircons from Gravels.*

Sometime since Mr. J. A. Edman of Meadow Valley, California, transmitted to the writer some heavy sands from gravel washings in California. One sample of these sands was composed largely of zircon-like crystals. The material came from a surface placer in Eagle Gulch near Edmanton about 4·5 kilometers southwest of Meadow Valley, Plumas County.

To make certain the character of these crystals some of the sand was digested on a water-bath with HF and H_2SO_4 concentrated for about two days. The residue was then washed and digested in HCl and water, again washed and digested in water alone to get rid of the dissolved material. The residue consisted chiefly of the zircon-like crystals with a few black grains, and a few specks of gold. Some of this residue was powdered and mixed with Na_2CO_3 and fused at a white heat in a little platinum crucible for five minutes. The culot was then washed in water. After the soluble material was removed there remained very abundant minute hexagonal crystals sup posed to be ZrO_2.

Some of the zircon crystals and the ZrO_2? were sent to Prof. S. L. Penfield of the Sheffield Scientific School, who kindly examined them and wrote that "the zircon crystals resemble ones which I have seen associated with gold from North Carolina. The forms are not unusual, 100, 110, 111, 311, and possibly 101. The hexagonal plates (referring to the crystals obtained by fusion with Na_2CO_3) resemble those I have met in testing for zirconia. I do not consider the reaction a very delicate one. The black grains may be chromite or some spinel mineral which would resist treatment with acids."

5. *Molybdenite.*

On the southeast slope of Mt. Hoffmann in the Yosemite National Park, at an altitude of about 9500 feet, is a lens composed of garnet, epidote, quartz and calcite. This lies in a narrow strip of gneissic rock at the contact with the granitic mass that lies just east. Possibly it represents a metamor-

phosed limestone mass. In some specimens (No. 2176 S. N.) of the material bright specks of a sulphide were noted. This mineral was determined by Mr. William Valentine as molybdenite.

About three miles north of west from Tower Peak in Tuolumne County is a considerable mass of quartzite, marble and black fine-grained gneiss. At the edge of the coarsely crystallized white marble, which has a width of about 400 feet, is a white schistose pyroxenic rock. Granitic rocks and quartz veins cut both the marble and the schist. The microscope examination of the granitic dikes showed them to be quartz-diorites containing primary augite and titanite. An excavation had been made on one of the quartz veins at the contact of the marble and schist. No doubt it was regarded as a gold- or silver-bearing lode. This vein contains a large amount of green epidote, garnet and zinc blende and a bright bluish metallic sulphide. This bluish sulphide was determined by Mr. Steiger and afterwards Mr. Valentine as molybdenite.

From a quartz vein in the granite on the south side of Knight Creek, northeast of Columbia in Tuolumne County, some specimens of quartz were collected by myself some years ago. The rock containing the vein is of a type called granodiorite in the Gold Belt folios. Molybdenite was found in these specimens. The quartz prospect was called the Dorsey claim, but should not be confused with a mine of the same name which has more recently been developed on the ridge north of Knight Creek.

6. *Tellurium, Selenium and Nickel in Gold Ores.*

The presence of tellurium in gold ores, especially in Calaveras and Tuolumne Counties, California, has been known for many years. In some mines, as the Bonanza at Sonora, tellurides are very abundant. The following new localities are given on the authority of Mr. W. J. Sharwood* of the University of California.

Tellurium and selenium were found in a mine on the Mother Lode near Table Mountain in Tuolumne County. The selenium was obtained as a red sublimate by heating some five or ten grams in a glass tube. The tellurium was detected in occasional specks by the sulphuric acid test applied to the powder spread over the surface of a shallow porcelain dish. Concentrated sulphides from the same mine were found to contain 1·5 per cent of nickel. The sulphides contain so much $MgCO_3$ as to be difficult of chlorination.

Mr. Sharwood also found tellurium minerals in isolated specks with pyrite, etc., in quartz from the Keltz mine near

*Communication by letter.

the south fork of the Stanislaus River and the Ham and Birney gold mine on Five Mile Creek, which is a branch of the south fork of the Stanislaus. Mr. Sharwood also found tellurium in a cavity in a fragment of unrounded coarse gold washed from gravel. This specimen is said to have come from Big Creek, Butte County, California.

7. *Carbonaceous Material in Quartz.*

Many of the veins of the Gold Belt region of the Sierra Nevada in the older rocks that lie east of the Mother Lode, are composed of quartz which is dark in color. The coloring material is so finely disseminated that a microscopic study of the slides of this dark quartz gives no clue to the nature of the coloring material. A specimen of this quartz from the Star Gold Mine on Rose Creek, which is a branch of the Stanislaus River, in Tuolumne County, was therefore selected for a chemical examination. The quartz was examined by Dr. H. N. Stokes, who reported "that the coloring matter is carbonaceous, not graphitic. Eight grams of the quartz, after the separation of sulphides, were treated with HF. This left several milligrams of carbonaceous residue, the nature of which was confirmed by conversion into $BaCO_3$." The Star Gold Mine is in Paleozoic rocks, the Calaveras formation of the Gold Belt folios.

8. *Berthierite.*

On the southwest slope of Mt. Gibbs, which is south of Mt. Dana in Tuolumne County, in an area of schists, are some heavy ledges of dark ore which have been exploited for silver. A specimen of the ore from one of these ledges was submitted to Prof. Munroe of the Columbian University in Washington for assay. The returns gave only a trace of gold and one and one-half ounces of silver per ton. This ore is therefore of no economic value. Some blow-pipe tests made by Mr. Steiger, under the direction of Prof. F. W. Clarke, showed that the ore contains iron, antimony and silver. Prof. Clarke surmised that the mineral berthierite might be present. More of the material was examined by Dr. H. N. Stokes, who reported:

"No. 879 S. N. is possibly berthierite, as it contains a large amount of iron, which dissolves together with the sulphide of antimony in cold strong HCl. The mineral is so impure, however, that it cannot be asserted positively that this iron does not come from some other iron mineral soluble in HCl. It is full of pyrite, galena or some other sulphide containing lead, as well as quartz and other minerals too intimately mixed to admit of separation. For this reason a quantitative analysis does not seem likely to give any definite results."

U. S. Geological Survey, Washington, D. C.

ART. LII.—*Mineralogical Notes on Anthophyllite, Enstatite and Beryl (Emerald) from North Carolina;* by J. H. PRATT.

Anthophyllite.—In 1890, Prof. S. L. Penfield described a single specimen of this mineral, which was reported as having come from the Jenks corundum mine near Franklin, Macon County, N. C. During the summer of 1892, while engaged with the North Carolina Geological Survey, Prof. Penfield and the author visited an outcrop of dunite, near Bakersville, Mitchell County, and on breaking open one of the loose bowlders of decomposed rock anthophyllite was exposed, which Prof. Penfield at once recognized as identical with the specimen he had described.

As there has been no mention of the correct locality of the anthophyllite and as this name is often applied to an enstatite occurring at the Jenks corundum mine, it has been thought that a description of the occurrence of these two minerals would be of interest.

At the Woody Place, two and a half miles south of Bakersville on the Marion road, there is a large outcrop of the rock, dunite. The hillside where it occurs is quite barren and thickly scattered with loose fragments and bowlders of the altered dunite. The outcrop has been carefully examined, but the anthophyllite has only been found in the bowlders. Here it occurs in prismatic crystals imbedded in penninite. Nearly all of the anthophyllite crystals are seamed and cracked, while those near the outer part of the bowlders are somewhat decomposed and stained a dirty brown. The purest crystals are transparent and vary from a pale clove-brown to a flesh-red color.

The crystals measure from 2^{mm} to 6^{mm} in the widest diameter, and some were found that were over three centimeters in length. A great many were examined, but no terminated ones were observed. The unit prism, 110, occurring alone or in combination with the brachypinacoid, 010, were the only forms observed.

An analysis of the anthophyllite by Dr. Baskerville* is given below, together with the results obtained by Prof. Penfield.† The two analyses are very similar and confirm Prof. Penfield's conclusion that the specimen described by him was from the Bakersville locality.

Anthophyllite has been found at Corundum Hill, but it is

*Of the Chemical Laboratory, N. C. Geological Survey.
† This Journal, xl, p. 396, 1890.

more fibrous and not of such good quality as that from near Bakersville.

	I (Baskerville).	II (Penfield).
SiO_2	56·40	57·98
Al_2O_3	1·15	·63
FeO	11·40	10·39
MnO	----	·31
MgO	28·68	28·69
CaO	·50	·20
H_2O	1·63	1·67
Loss at 100°	----	·12
	99·76	99·99

Enstatite.—The enstatite from Corundum Hill, that is commonly called anthophyllite, occurs as a rock composed of a mass of interlocking bladed grayish crystals. The rock is very tough and tenacious and forms a perfectly continuous mass with the dunite, which is exposed over nearly the entire surface of the hill.

The analysis of this mineral by Dr. Baskerville* is as follows:

		Ratio.	
SiO_2	51·64	·861	
Al_2O_3	·12	·001	
FeO	9·28	·129	·943
MnO	·56	·008	
MgO	31·93	·798	
CaO	·45	·008	
H_2O	5·45	·303	
	99·43		

It is evident from the amount of H_2O found that the material analyzed was impure, and as shown by the calculations below, the ratio in the above analysis corresponds to a mixture of 44·5 per cent enstatite, 35 per cent serpentine and 20·5 per cent talc. The analysis is also given below after substituting for MnO and CaO their equivalent of MgO, deducting Al_2O_3 and recalculating to 100 per cent.

	44·5 per cent. Enstatite.	Ratio.	35 per cent. Serpentine.	Ratio.	20·5 per cent. Talc.	Ratio.	Total.	Recalculated Analysis.
SiO_2	24·42	·407	14·87	·246	13·02	·217	52·31	52·19
FeO	7·58	·105	1·84	·025	----		9·42	9·39
MgO	12·50	·312	13·83	·346	6 51	·163	32·84	32·91
H_2O	----		4·46	·246	·97	·054	5·43	5·51
	44·50		35·00		20·50		100·00	100·00

* N. C. Geological Survey, Bull. 11, p. 27.

Enstatite (*Bronzite*).—The occurrence of a bronzite diopside rock (websterite) in the midst of an outcrop of dunite, near Webster, Jackson County, N. C., has been described by Williams* and Lewis.† Near the western border of this outcrop bowlders were observed that were composed almost entirely of bronzite.

The mineral is of a resinous brown color and of a bronze-like luster even on the unaltered surfaces. No distinct crystals were observed, the specimens being a mass of interlocking crystals making a very tough rock similar to the enstatite described above. The material for analysis was carefully selected by hand picking, and showed no impurities or decomposition when examined with the magnifying glass. The analysis of this mineral by Dr. Baskerville is given below:

		Ratio.		
SiO_2	53·62	·894		= 1·
Al_2O_3	·97	·009	·012	
Cr_2O_3	·50	·003		
FeO	9·06	·125		
CaO	1·75	·031	·994	= 1·11
MgO	33·53	·838		
H_2O	·19	·001		
	99·62			

In the above analysis the ratio of the bivalent oxides to silica is close to 1 : 1 and of ferrous oxide to magnesia and lime is very near to 1 : 7; this would give the formula (MgFe) SiO_3 with Mg : Fe = 7 : 1.

Assuming that the Al_2O_3 and Cr_2O_3 belong to spinel, and deducting RO sufficient to combine with them, the analysis, after substituting for CaO its equivalent of MgO and recalculating to 100 per cent, is given below, together with the theoretical composition.

	Found.	Theory for (Mg,Fe)SiO_3; Mg : Fe = 7 : 1.
SiO_2	55·35	57·69
FeO	9·14	8·65
MgO	35·51	33·66
	100·00	100·00

The name bronzite is very appropriate for this Webster enstatite, as the luster is of a decided bronzite-like character throughout the entire mass, and it is undoubtedly not of secondary origin. A similar bronzite has been found at the Buck Creek, Cullakeenee, corundum mine in Clay County.

* American Geologist, vi, pp. 43–4, 1890.
† N. C. Geological Survey, Bull. 11, p. 27.

Beryl (*Emerald*).—Although the beryl is a very common accessory mineral in granite veins, especially those of a pegmatitic character, it is not common to find the deep emerald-green variety. The earliest report of the emerald in North Carolina is by Hidden,* who describes the occurrence in Sharpes Township, Alexander County, where it is found associated with the emerald-green hiddenite.

On the divide between Brush and Crabtree Creeks, about four miles south of Spruce Pine post office, Mitchell County, emerald has been found in a pegmatitic vein consisting chiefly of quartz and an albite feldspar, with tourmaline and garnet as accessory minerals. The county rock is gneiss and biotite schist.

The emerald has the characteristic green color of the gem, and some of the crystals are transparent. No terminated crystals were observed, but all have the prism zone well developed. The crystals vary in size from less than a millimeter up to eight millimeters in diameter.

The color of the crystals varies with their location in the vein, those nearest the schist being of the emerald variety, while those farther away are pale green or yellowish. The yellowish or cream-colored beryls are very abundant through the vein and vary in size, from those hardly 2^{mm} in diameter to one that measured 17^{cm}.

North Carolina Geological Survey, March, 1898.

*Journal Elisha Mitchell Scientific Society, 1880.

Art. LIII.—*The Bethany Limestone at Bethany, Missouri;* H. Foster Bain.

The Coal Measures of the Iowa-Missouri coal field are made up of the well-marked series of beds known respectively as the Des Moines and the Missourian. As originally used* these terms were considered to rank as stage names, but as the work of geologic mapping has progressed in the two states it has been found that both the Des Moines and the Missourian formations are really series of quite well-marked beds. Keyes has already proposed† that the terms be considered as serial and many of the minor divisions or stages have been made out in Iowa,‡ Missouri,§ and Kansas.‖

The complete section of the Missourian series has not been published, though individual formations falling within its limits have been made out by Haworth,¶ Prosser,** Keyes and others. Among the minor division the basal member of the Missourian has been often referred to. It is a heavy bed of limestone, or really a group of limestones with their intercalated shale beds, and its outcrops have been mapped, in part in detail and in part by reconnoissance work only, in Iowa, Missouri and Kansas. The limestone is of considerable economic importance, not only because it furnishes stone for building and lime-burning but also because it marks the upper limit of the productive Coal Measures throughout most of the region. It is accordingly particularly important that there should be no mistake in its correlation. There has been some controversy as to the proper name to be applied to the bed,†† but the term Bethany or Bethany Falls seems to have priority. In the present paper it will be shown that it is not the particular limestone which forms the falls which is of significance, but a whole group of limestones, all of which are well shown within the limits of the town of Bethany, Missouri. In view of this fact the suggestion already made, that the latter portion of the name as first used be dropped, seems particularly good.

In the recent work of the Iowa Geological Survey detailed sections of the Bethany limestone have been made out at intervals from the central portion of the state, where it passes beneath the Cretaceous, to the southern border, where it is well

* Keyes: Mon. Rev. Iowa Weather Service, vol. iv, p. 3, 1893.
† Amer. Geol., vol. xviii, pp. 22–28, 1896.
‡ Iowa Geol. Surv., vol. v, pp. 378–398; ibid, vol. vii, 443–450, 509–520, 1897.
§ Missouri Geol. Surv., vol. x, pp. 29–71, 1896.
‖ Univ. Geol. Surv. Kansas, vol. i, pp. 145, 193, 1896.
¶ Loc. cit.
** Jour. Geology, vol. iii, p. 800, 1895.
†† This Journal, IV, vol. ii, pp. 221–225, 1896.

shown on Grand River. Bethany is but a few miles beyond the Iowa border and along Big Creek at this point the same beds, seen first in central Iowa, are well exposed. It was at Bethany that Broadhead* first studied the limestone. As now exposed the beds yield the following sequence, along a small tributary of Big Creek running through the town. The first exposure, which shows the top of the Bethany, is near the railway bridge north of the depot, the top of the limestone being at about 888 A. T.

6. Limestone, fragmental, loosely cemented, with many specimens of *Meekella striatocostata, Chonetes verneuiliana, Productus costatus, Athyris subtilita, Productus longispinus, Spirifer cameratus* and *Dielasma bovidens* 6
5. Shale, clayey, green to drab with thin bands of limestone... 2
4. Shale, clayey, drab to black 2
3. Limestone, drab blue, two ledges, 9 and 3 inches thick..... 1
2. Shale, black 1
1. Shale, black to drab, with irregular nodules and thin layers of impure black limestone carrying large well-formed *Productus cora, Productus nebrascensis, Athyris subtilita, Myalina subquadrata* (?), *Schizodus*, sp.? In the shale itself are *Myalina subquadrata, Productus nebrascensis, Athyris subtilita, Rhombopora lepidodendroides* and plates of *Eupachycrinus verrucosus* 6

Below this exposure for some distance there are no outcrops, but in the western part of town there are some small quarries which show the following beds:

	Feet.	Inches.
6. Shale, clayey, drab		6
5. Shale, calcareous, transition beds, with *Spirifer cameratus, Meekella striatocostata, Productus cora, Productus costatus, Productus nebrascensis, Rhombopora lepidodendroides, Fistulipora nodulifera, Myalina subquadrata, Athyris subquadrata*, and *Derbya crassa*	1	6
4. Limestone, heavy ledges, many *Fusulina cylindrica*	2	10
3. Limestone, thin-bedded with many of the fossils collected above, particularly *Athyris subtilita, Productus cora, Productus costatus, Spirifer cameratus*, and *Meekella striatocostata*	10	
2. Unexposed	8	
1. Limestone, thin-bedded, with *Productus costatus, Productus cora, Productus longispinus, Athyris subtilita, Spirifer lineatus, Spirifer cameratus, Spirifera kentuckensis, Chonetes verneulianus, Hustedia mormoni, Dielasma bovidens* and *Fusulina cylindrica*	12–15	

*Trans. St. Louis Acad. Sci., vol. ii, pp. 311, 1862; Mo. Geol. Surv. Iron Ore and Coal fields, Pt. II, p. 77 et seq. 1873.

Not far from here is the mouth of the stream which is just above the falls of Big Creek. The rock forming the falls lies probably 6 to 8 feet below the base of the limestone just described. It is about 20 feet thick, the upper 18 feet being made up of a coarse but firmly cemented limestone breccia. It is marked by long dark streaks which suggest corals but which fail to show structure. The only fossil collected from it was *Productus cora*. Below the breccia is about two feet of fine-grained gray limestone, carrying large well-formed *Spirifer cameratus* with *Productus cora*. The brecciated character of the limestone and the absence of marked sedimentation plains has given under water action rounded forms and knob and pot hole surfaces.

The general sequence found here, with the four bodies of limestone separated by shales, is the same as has already been found in central Iowa. The exposures in the latter region were first studied by White* and have been more recently reviewed by the present survey.† In many of the minuter details even, there is a close correspondence between the Bethany section and that of Madison and adjacent counties. The latter may be summarized as follows:

	Feet.
8. Limestone, thick and thin-bedded, characterized by a particular abundance of *Fusulina cylindrica*, and hence called the Fusulina limestone	15–30
7. Shales, predominantly dark-colored and argillaceous, containing several thin bands of bituminous limestone which are usually quite fossiliferous. About midway of the shales is a horizon which is particularly fossiliferous. The more usual forms, including Athyris, Productus and Spirifer, occur in great abundance and perfection. With these forms are vast numbers of *Derbya crassa* with *Myalina subquadrata*, *Myalina kansasensis*, *Myalina swallowi*, *Aviculopecten occidentalis*, *Productus nebrascensis*, etc. Not far above this horizon is usually a thin band of limestone literally made up of *Chonetes verneulianus*. The whole thickness of shale is	10–20
6. Limestone earthy, magnesian, easily disintegrating above to medium grained coarse-bedded quarry rock below	10–20
5. Shale, usually dark and including a black bituminous horizon	8–12
4. Limestone, well shown near Earlham and hence called the Earlham limestone. It carries an abundant fauna which will be noted later	20

* First and Second Ann. Repts. State Geol., pp. 71–72, 1868; Geol. Iowa, vol. i, pp. 245–250, 1870.

† Trans. Iowa Acad. Sci., vol. i, pt. iii, p. 144, 1895; Iowa Geol. Surv., vol. iii, p. 137, 1895; ibid., vol. vii, pp. 446–451, pp. 491–539, 1897.

3. Shale, with bituminous horizon and at many points a thin black limestone 3–8
2. Shales, sandy, light-colored, very variable thickness ... 2–16
1. Limestone, fragmental, made up of irregular bits of lime rock filled in with calcareous clay. In places the rock can be picked to pieces with the fingers; elsewhere it hardens up into massive thick-bedded layers. Along a small tributary of Deer Creek in Guthrie County it is quite fossiliferous, yielding *Spirifer lineatus, Spirifer cameratus, Athyris subtilita, Hustedia mormoni, Productus longispinus, Naticopsis altonensis, Lopophyllum proliferum, Orthis pecosi, Bellerophum* sp., *Strapharrollus* sp., *Archæocidaris* sp..... 10–15

The Earlham limestone in Madison County is one of the best developed and most easily recognized members of the section. At Robertson quarry, two miles east of Earlham, the following section was noted:

	Feet.	Inches.
11. Bed of soft, yellowish, magnesian, earthy limestone, decomposing readily when exposed to weather	4	
10. Limestone in three heavy ledges at west end of quarry	4	
9. Buff shale with *Chonetes verneulianus*		4
8. Limestone, like number 4	2	
7. Ashen shale with very few fragments of brachiopod shells		6
6. Earthy limestone, decomposing readily, yellowish, carrying large individuals of *Athyris subtilita*		4
5. Drab shale, with *Productus longispinus, P. costatus,* crinoid stems and fragments of other fossils		6
4. Quarry limestone, in thin layers, irregularly bedded	8	
3. Unexposed	20	
2. Sandstone, in heavy layers	7	
1. Base of sandstone to creek, unexposed	17	

At one point the quarrymen had worked down in the bottom of the quarry and exposed, below number 4, drab and black shales to the depth of three feet, and below the shales a ledge of limestone six inches in thickness.

Distributed through the limestone beds No. 4 are the following:

Lopophyllum proliferum McChesney.
Stem segments and body plates of crinoids.
Various species of Bryozoa.
Meekella striatocostata Cox.
Productus punctatus Martin.
P. costatus Sowerby.

P. longispinus Sowerby.
P. cora D'Orbigny = *P. prattenianus* of authors.
Athyris (*Seminula*) *subtilita* Hall.
Hustedia mormoni Marcou.
Spirifer cameratus Morton.
Spiriferina kentuckensis Shum.
Allorisma subcuneatum M. & H.

Chonetes verneulianus N. & P. is somewhat common in No. 9 but is very rare in the other members of the section. *Spirifer cameratus* and *Productus longispinus* are most abundant near the base of No. 4, while *Productus costatus* and *Athyris subtilita* are more common in the upper layers. All the species enumerated, however, with the exception of *Allorisma subcuneatum*, range through all the beds making up No. 4.

The best exposures of the Bethany limestone in southern Iowa are found along Grand River and its tributaries. From the outcrops found there a complete section can be made from the Fragmental limestone at the base up to and above the beds which farther north have been called the Fusulina limestone, but which from their excellent development in that vicinity may now perhaps be best called the De Kalb limestone.

In Union County there is an important bed of limestone which from the fact that it is well shown on Sand Creek, near Westerville, may be called the Westerville limestone. It lies some little distance above the De Kalb horizon. In Jones township section 28, and farther south along the river, the beds are exposed, showing the following section:

5.	Limestone, ash gray, fine-grained, thin-bedded, becoming almost shaly at the top, with *Productus cora*, *Productus costatus*, *Spirifer cameratus*, *Athyris subtilita*, *Chonetes verneulianus* cf. *glabra*, *Lopophyllum proliferum*, *Straparollus subquadratus* and Fenestelloid bryozoa	10
4.	Shale, gray, calcareous, with thin nodular bands of limestone	4
3.	Shale, drab to black	10
2.	Limestone, impure nodular in two bands	2½
1.	Shale, drab to black, well exposed at Westerville	8

These beds extend into Decatur County, being seen near Westerville on Sand Creek and on Grand River. It seems probable that the shale (No. 1) extends down to the top of the De Kalb or Fusulina limestone, which is exposed near Grand River and was at one time quarried at the old Madarasz quarry (Sec. 36, Tp. 70, W., R. xxvii W.). The best exposures of the latter limestone and the ones which may be taken as typical are found a short distance east of De Kalb station (Sec. 28, Tp. 70 N., R. xxvi W.). The section at this point is given below.

	Feet.	Inches.
5. Limestone, irregularly water-worn		6
4. Shale, hard, drab		6
3. Limestone, irregularly bedded		8
2. Shale, calcareous, becoming in places a poor grade of lime rock	2	
1. Limestone in thick to thin ledges	4	

The limestone is quite fossiliferous, the forms collected including: *Productus costatus*, *Productus longispinus*, *Athyris subtilita*, *Spirifer camerata*, *Spirifer kentuckensis*, *Dielasma bovidens*, *Derbya crassa*, *Lopophyllum proliferum* and *Fusulina cylindrica*. This fauna is more abundant than is usually found in the same beds farther north, though no extensive collections have been made in the latter region and many of the species collected at De Kalb are known to be present, sparingly at least, in the Madison County outcrops. The marked predominance of the *Fusalina cylindrica*, which is so striking a characteristic of these beds in Madison County, is not so noticeable at De Kalb. This is probably due as much to the greater abundance at the latter point of the other forms mentioned as to any real decrease in the numbers of the Fusulina. It is nevertheless true that the Decatur County outcrops show much closer relations to the rocks as developed at Bethany than to the Winterset section in the earlier advent, or at least culmination, of Fusulina. It is for this reason in part, that the term De Kalb limestone is to be preferred to Fusulina limestone, since neither the presence nor the abundance of the latter form is found to be consonant with a constant stratigraphical horizon.

The beds below the De Kalb limestone are well developed and show no important variation from the standard sections already given. A point of interest is the persistence of the Myalina horizon, which is found on Grand River west of the town of Decatur only less perfectly developed than at Winterset.* The exposures in and near Davis City show the Earlham and Winterset limestone especially. The Fragmental limestone is shown but is almost non-fossiliferous, as at Bethany. As seen in Clarke County near Osecola it is also unfossiliferous, and the only abundant collections from this horizon were made in the central Iowa counties.

No attempt has been made to follow the subdivisions of the Bethany south of its type locality. Their persistence in Iowa however, with certain hurried observations at Kansan City and a study of the reports of the University Geological Survey of Kansas, indicates that a portion of the section at least may be

*Geology of Decatur County, Iowa Geol. Surv., vol. viii. In press.

looked for in the latter region. The persistence of these minor subdivisions over the territory where they have already been traced for more than one hundred and fifty miles, suggests that the differences are due to widely acting causes and brings into sharp contrast the unsettled and disturbed conditions which apparently prevailed during the deposition of the Des Moines beds.

This manifest change in conditions affords a legitimate basis for making the Bethany the dividing line between the two divisions of the Coal Measures, even though it be recognized that the faunal changes are in the proportion and abundance of the species present rather than in the introduction of new forms. The old fauna adapted itself to the new conditions and there was a change merely in the balance between the species.

The taxonomic rank of the Bethany and its subdivisions is indicated in the following table:

System	Series	Stage	Substage
Carboniferous	Missourian	Undifferentiated	
		Bethany	Westerville?
	Des Moines		De Kalb Winterset Earlham Fragmental

It is probable that the Westerville limestone will be found to be better included with the next higher division when that shall be studied, but for the present it may be conveniently considered in connection with the Bethany.

Des Moines, Iowa, April 18, 1898.

Art. LIV.—*A Psychrometer applicable to the Study of Transpiration;* by Robert G. Leavitt.

The rate at which the vapor of water is exhaled from plants has been quantitatively examined by three principal methods, viz.: (1) by noting the weight of water taken up by the plant, (2) by weighing the growing plant, with pot or jar, before and after the loss of the vapor in question, and (3) by collecting and weighing the escaped vapor itself. The first mode was employed by Woodward in 1699. The second method has been in general use since Hales's early experiments (1724). The collection of the transpired water has been accomplished either by means of an hygroscopic substance (Garreau, 1849), or by condensing it on the walls of a receptacle (Dehérain, 1873).

There remains the possibility of testing the air brought from a transpiring part for the amount of vapor present, without actually collecting the vapor. If the dew-point could always be speedily and accurately ascertained, it was thought that this would be the foundation of a method having some advantages; as, for example, in case it were desired to detect changes in short intervals of time.

The dry hygrometers in use, such as Dines's and Alluard's, require a steady fall of temperature until the dew is perceived upon the collecting surface. This changing of temperature creates a considerable uncertainty as to the actual point at which dew begins to form. The difficulty may be overcome by employing several hygrometric surfaces, at adjustable fixed temperatures, side by side. In the instrument to be described there are four nickel-plated tubes passing vertically through a glass chamber. Each conducts a stream of water and has a thermometer within it. The water is derived from two sources, warm and cold, in order that the temperature may be regulated at will. The water-tanks are of such capacity and the flow is so even, that the mixed streams maintain sensibly constant temperatures for many minutes together. Above the chamber the hygrometric tubes are of glass, allowing the thermometers to be read.

Through the chamber a steady current of air is drawn, bringing the transpired vapor from the receptacle holding the plant. The draft having been so suited to the activity of the plant as to give a dew-point within the range of temperatures at command, the tubes are set, let us say, at 6°, 10°, 14°, and 18°. If No. 1 alone shows dew the fact is noted, the warm water turned on to throw off the gathered moisture, and

the other three tubes set at 7°, 8°, and 9°. Should No. 2 show dew at 7°, No. 3 none at 8°, the dew-point is between these temperatures, and is found at the next move within one or two-tenths of a degree. When two tubes stand side by side, one at a constant temperature of 7°·1, dimmed with moisture, while the other at 7°·2 is free, the dew-point is known with certainty within one-tenth of one degree. The thermometers are graduated to tenths, and of course have been carefully compared.

The following experiment, made in the course of a study on the water-changes in a young bean-plant during sleep-movements, may be of interest as illustrating the workings of the method.

Plant, a bean-seedling with 10 leaves, in pot wrapped with rubber and placed under bell-jar of 8 lr. capacity. Heavy clouds, dull light. Temperature in bell-jar throughout 20°·25 C. Draft, 972 ± 5^{cc} per minute.

Time.	Dew.	No dew.	Conditions, etc.
11 : 23 A. M.	8°·5 C.	8°·8 C.	Leaves erect. Plant now first darkened.
11 : 27	Not found.	8°·1	
11 : 30	"	7°·9	Little or no drooping. 11 : 38, lower leaves have declined by 45°.
11 : 42	6°·	6°·3	
11 : 53	No change.	No change.	Plant half asleep.
12 : 05	"	"	No change.

The plant manifested nyctitropic movements only slowly, and never completely assumed a sleeping position. Diminution in the rate of transpiration was indicated in 4 minutes after change of light, by a fall of at least 0°·4 in the dew-point; in 7 minutes by a fall of over 0°·6; and in 19 minutes a nearly constant transpiration at a lower rate was definitely ascertained, giving a dew-point between 6°· and 6°·3. As exact weights of water exhaled were not sought, a nearer determination of the dew-point was not made.

Botanical Laboratory of Harvard University,
May 4, 1898.

Art. LV.—*The Action of Carbon Dioxide on Soluble Borates;* by Louis Cleveland Jones.

[Contributions from the Kent Chemical Laboratory of Yale University.—LXX.]

In a process for the separation and estimation of boric acid devised by Morse and Burton,* the liberation of carbonic, silicic and boric acids from a mixture of inorganic salts is effected by the action of sulphuric acid, using tropaeolin *OO* as an indicator of acidity. In the solution thus prepared, containing in free condition only carbonic, silicic and boric acids, the silicic acid is dehydrated and made insoluble by anhydrous copper sulphate. The boric acid is then extracted with absolute alcohol. To this alcoholic solution of boric acid, a known amount of barium hydroxide solution is added in excess over that required to form a barium metaborate, BaB_2O_4. Carbon dioxide is then passed into the solution in accordance with the hypothesis that the excess only of barium is acted upon. The aqueous mixture of barium metaborate and barium carbonate is evaporated and the residue is heated to a constant weight over a triple burner. From the following proportion the boric acid present may be calculated. The molecular weight of boric acid—the molecular weight of carbon dioxide : the molecular weight of boric acid=the total weight found—the theoretical weight of barium as carbonate : the weight of boric acid present. It is obvious, inasmuch as the difference between the calculated weight of the barium as carbonate and the actual weight of the residue is multiplied nearly three times to get the boric oxide, that the actual error of the process, whatever it may be, is magnified three-fold by the method of computation.

I have made a study of this method applied to pure boric acid, but have been unable to obtain results similar to those of Morse and Burton.

For this investigation boric acid of standard strength was made by dissolving in a given amount of water a known weight of anhydrous boric oxide, prepared by igniting over a blast lamp boric acid several times recrystallized and washed. A solution of barium hydroxide was filtered free from carbonate and then standardized by precipitation as carbonate and also by the Phelps method with iodine.† To a measured amount of the boric acid solution an excess of barium hydroxide was added, carbon dioxide passed, and the whole evaporated and by successive ignitions brought to a constant weight. Below are tabulated some of the results :

* Am. Chem. Jour., x, 154.

† This Journal, ii, 70.

	$Ba(OH)_2$ taken. Calculated as $BaCO_3$. grm.	B_2O_3 taken. grm.	Weight of residue after successive ignitions. grm.	B_2O_3 found. grm.	Error. grm.
I....	0·9391	0·2200	1st wt., 0·9860	0·1263	−0·0937
			2d " 0·9786	0·1063	−0·1137
II...	0·9318	0·1295	1st " 0·9605	0·0744	−0·0523
			2d " 0·9558	0·0646	−0·0649
			3d " 0·9510	0·0517	−0 0778
III..	0·9253	0·2192	1st " 1·0357	0·2972	+0·0780
			2d " 1·0248	0·2679	+0·0487
			3d " 1·0149	0·2412	+0·0220
			4th " 1·0064	0·2183	−0·0009
			5th " 0·9975	0·1944	−0·0248
			6th " 0·9855	0·1621	−0·0671
IV ..	0·7301	0·0810	1st " 0·8017	0·1927	+0·1117
			2d " 0·7777	0·1281	+0,0471
			3d " 0·7642	0·0918	+0·0108
			4th " 0·7582	0·0757	−0·0053
			5th " 0·7517	0·0582	−0·0228
			6th " 0·7482	0,0487	−0·0323
			7th " 0·7447	0·0393	−0·0417
			8th " 0·7427	0·0339	−0·0471
			9th " 0·7422	0·0326	−0·0484
			10th " 0·7407	0·0285	−0·0525

Plainly the results vary with the degree of the ignition. At the outset the residue may or may not weigh more than the theory requires for the known amounts of barium hydroxide and boric acid taken upon the assumption that the residue is barium metaborate and barium carbonate. This is obviously natural, if the carbon dioxide acts upon the barium borate as well as upon the excess of barium hydroxide; for, it is to be expected that in the evaporation more or less of the free boric acid will volatilize, and that in the subsequent ignition the boric acid remaining will tend to recombine more or less completely, replacing carbon dioxide. If the boric acid present were to recombine completely with the barium carbonate to form a metaborate, the final result would always be low by just the amount of free boric acid volatilized in the process of evaporation and ignition. The evidence of an experiment, however, in which 0·25 grm. of previously prepared barium metaborate was fused in contact with 0·5 grm. of barium carbonate, resulting in a loss of 0·0871 grm., goes to show that the metaborate and carbonate of barium interact still further to liberate carbon dioxide.

These results were so surprising in the light of the experience of Morse and Burton that the question of the possibility of breaking up by carbon dioxide the barium metaborate

already formed was put to the test directly. A known amount of barium hydroxide was taken in solution and to it added an amount of boric acid very little in excess of that theoretically necessary to form the barium metaborate. The solution was evaporated to dryness and the residue ignited. The weight obtained proved to be 0·0008 grm. less than the sum of the barium and boric oxides taken, doubtless because the slight excess of boric acid was somewhat volatile in the evaporation. The mass, presumably barium metaborate, was now dissolved as completely as possible in hot water, carbon dioxide was passed through the solution, the whole was evaporated, and the residue ignited and weighed. The increase in the weight showed that carbon dioxide had been absorbed, while a corresponding amount of boric acid had not volatilized.

	$Ba(OH)_2$ taken. Calculated as $BaCO_3$. grm.	B_2O_3 taken. grm.	Residue after ignition. grm.	Residue after CO_2 treatment and ignition.—grm.
V	0·8377	0·2990	0·9491	—0·9771

After passing in carbon dioxide and igniting, the increase in weight was 0·0280 grm., representing the gas absorbed less the boric acid volatilized.

It was plain that barium metaborate is decomposed in solution by carbon dioxide. The possibility remained, however, that the action of carbon dioxide might be so regulated as to leave the metaborate practically unattacked. In experiment VI, therefore, carbon dioxide was passed above the stirred solution until no further precipitate formed upon the surface, the barium present being in excess of that required to form a metaborate.

	$Ba(OH)_2$ taken. Calculated as $BaCO_3$. grm.	B_2O_3 taken. grm.	Weight of residue after ignition. grm.	B_2O_3 found. grm.	Error. grm.
VI ..	0·7094	0·2070	0·7710	0·1658	—0·0412

The variation of this result from the theory shows that under these conditions the metaborate is not unaffected by carbon dioxide, the loss being due, of course, to the escape of boric acid.

An attempt was now made therefore to gauge the amount of the carbon dioxide introduced by means of an indicator. In experiment VI phenolphthalein was added to the solution of boric acid containing an excess of barium hydroxide and the current of gas was stopped when the color of the indicator disappeared.

	$Ba(OH)_2$ taken. Calculated as $BaCO_3$. grm.	B_2O_3 taken. grm.	Weight of residue after ignition. grm.	B_2O_3 found. grm.	Error. grm.
VII.	0·6073	0·1573	1st wt., 0·6820	0·2011	+0·0438
			2d " 0·6783	0·1911	+0·0338
			3d " 0·6720	0·1742	+0·0169
			4th " 0·6700	0·1688	+0·0115
			5th " 0·6655	0·1567	−0·0006
			6th " 0·6630	0·1499	−0·0074
			7th " 0·6609	0·1443	−0·0130

This result is manifestly an improvement over those obtained without the careful restriction of the supply of carbon dioxide. A similar experiment, differing only in the single point that the carbon dioxide was made to act upon a boiling solution, resulted in like manner.

In the light of these observations it is plain that a sufficiently prolonged action of carbon dioxide should result in the displacement of all the boric acid if that acid can be removed from the field of action as fast as it is liberated. Experiments were made which clearly demonstrate the truth of this hypothesis. A small side-necked flask was charged with a solution of boric acid (0·1143 grm.) and barium hydroxide (0·3227 grm.) in proportion to form the metaborate. The mass was brought nearly to dryness by distillation and methyl alcohol (15^{cm^3}) added. Through this flask, in which the alcohol was kept boiling by a Bunsen burner, was passed the vapor of methyl alcohol, while carbon dioxide, purified by a neutral solution of silver nitrate, bubbled continually through the entire system. The methyl alcohol vapor coming from the side-neck flask was kept lighted by contact with the flame of a Bunsen burner and the distillation continued for two hours until the flame showed not the slightest tinge of green. The residue in the flask originally containing barium metaborate was brought to dryness and tested for boric acid. Only a trace was found and this was thought to be due to inclusion by the insoluble barium carbonate. In a similar experiment in which borax was used instead of barium borate, no trace of boric acid was found in the residue of sodium carbonate, either by tumeric or the flame test, while the distillation was continued only one-half the time of the preceding experiment. This result is quite in harmony with the views of P. Georgevic* to the effect that the large absorption of carbon dioxide in solutions of borax indicates that the boric acid is displaced from its union with the base.

Obviously, the division of the base between boric acid and

* Jour. Prac. Chim., xxxviii, 118.

carbonic acid falls under the principle of mass action, and if the boric acid is taken in sufficient excess over the barium hydroxide, the action of the carbonic acid should be inappreciable. This idea is sustained by an experiment in which about 1 grm. of boric acid was dissolved with 0·15 grm. of barium hydroxide. No precipitate could be obtained by passing carbon dioxide and boiling. In fact, in the French process of borax manufacture just this action of an excess of boric acid upon a boiling solution of sodium carbonate is used. On the other hand to prevent the formation of a carbonate this excess of boric acid must be considerable if the action of carbon dioxide is prolonged. Thus in an experiment in which a current of carbon dioxide was passed into a solution containing 0·1219 grm. of boric anhydride and one-half the amount of barium needed to form a metaborate, the solution (60^{cm}) deposited on boiling ninety per cent of the barium present in the form of the carbonate.

In view of the facts which I have described, it is difficult to see under what conditions Morse and Burton prevented the excessive action of carbon dioxide and obtained in their analytical method the excellent results which they record.

I wish to express my thanks to Professor Gooch, whose advice has been constantly sought and freely given.

ART. LVI.—*The Jerome (Kansas) Meteorite;* by HENRY S. WASHINGTON.

THE meteorite, described in the present paper, was acquired for the Yale University Collection about a year ago, through the generosity of members of the Class of 1857. Prof. Dana entrusted it to me for examination, for which kindness I desire to express my hearty thanks.

Little is known of the circumstances of its finding, and all that could be ascertained was published by Prof. Dana in a note in the Yale Alumni Weekly for May 6, 1897, from which I quote the following:—

"It was found April 10, 1894, by Mr. H. T. Martin, on the Smoky Hill River, Gove Co., Kansas, about 15 miles east of Jerome. Mr. Martin was then engaged in hunting fossils, and his attention was attracted by this mass, whose appearance was quite foreign to the rock of the neighborhood. It proved on examination to be a meteorite, of the circumstances of whose fall nothing has been learned. The same State has furnished a number of other meteorites at points considerably distant from that where the present one was discovered, and it is possible that some of them may prove to have been parts of the same original meteor. . . . The stone has been placed in the center of the case devoted to meteorites in the mineral room of the Peabody Museum."

As the Smoky Hill River is several hundred miles long, and other meteorites may be found in the extended area of Gove Co., I propose for this mass the name of the Jerome Meteorite, after the nearest town.

The stone consists of several pieces, the largest weighing about 62 lbs. (30 kilos), with several smaller fragments, the largest of which weighs $2\frac{1}{2}$ lbs. and collectively $3\frac{1}{4}$. One of these was apparently broken off at the time of fall, as none of its surfaces are those of a fresh fracture.

The main mass measures some 12 inches in its largest diameter, the other dimensions being between 9 and 10 inches; it has roughly pointed ends, and its polyhedral form is vaguely suggestive of a dodecahedron drawn out in the direction of its vertical axis. One end is quite sharply pointed, while the other is blunter and irregular, showing some fresh and other older fracture surfaces, and is apparently the point of impact. From this broken surface a number of fine cracks radiate through the body of the mass.

The mass is bounded by fairly plane surfaces, some being quite flat, while others are more or less warped. The angles

are rounded. A few shallow pits are seen, and here and there ovoidal nodules, which project slightly above the main surface, or from the bottoms of shallow depressions. These measure several centimeters in length, with a width of about two-thirds of the length.

A thin, dark brown crust covers the surface, but this has suffered through atmospheric decomposition, and is much corroded, lacking in places, and often dull and rusty. No signs of ridges or other flow phenomena are to be seen on what is left of the crust. Small, rough, wart-like processes are seen generally over the surface, some due apparently to the projection of chondrules through weathering, while others are the less altered fragments of crust.

Parts of the meteorite, especially near the point of impact, and the fragment ($\frac{3}{4}$ lb.) which shows no fresh fracture surfaces, are covered with a fine, yellowish white powdery substance, which effervesces but slightly in acid, and is apparently a light clayish soil. The same substance is found in the cracks previously mentioned.

The fresh fracture is uneven, and the stone, as thus seen, is fine-grained and compact. The general color is dark rusty brown, which under the lens is seen to be a mottled brown and black. Small, glistening streaks of nickel-iron are scattered through it, but no troilite was seen. The lens also reveals translucent grains of olivine and bronzite. Small rounded chondrules are also seen here and there, but are not very numerous.

It is very evident that the oxidation of the iron from weathering extends far into the mass, though possibly a section through its center might reveal fresh substance. Of the stones in the Yale collection it resembles most that from Salt Lake City, and is also much like the decomposed portions of the Bluff, Fayette Co., Texas, meteorite.

Under the microscope the stone is seen to be composed of quite numerous chondrules of bronzite and olivine, with fragmental crystals of olivine, bronzite and a little pyroxene, in a rather brecciated groundmass of the same minerals, together with some interstitial matter, which seems to be glass. Nickel iron is present in the form of small, anguiar, irregular masses. Patches and veins of dark, reddish-brown, and yellow ferruginous substance are present, and show that considerable atmospheric decomposition has taken place. A few small fragments of plagioclase are also to be seen, but no troilite, and nothing which could be referred with certainty to maskelynite.

On the whole I am inclined to class this stone with Brezina's group 37, "krystallinisch Chondrit, breccienähnlich

(ckb)," * though I have no sections of either of his two examples for comparison. It will be remembered that it resembles megascopically the less fresh parts of one of these, the Bluff meteorite.

The chondrules of bronzite run up to nearly 2^{mm} in diameter, and show, in most cases, circular sections, or nearly so, though angular and fragmental forms are seen. They present the usual fibrous, eccentrically radiated structure.

The olivine chondrules are somewhat larger, up to 3^{mm} and show greater variety. Many are monosomatic, with parallel plate structure and border as figured by Tschermak.† The interstitial matter here is granular, colorless and isotropic, containing small, black, opaque particles. It is possibly a glass, as in the cases described by Tschermak, though its pronounced granular character is against this view, and points rather to the idea that it is maskelynite. These chondrules are usually small and round.

Porphyritic olivine chondrules are more numerous, as well as the largest in size, and are occasionally rounded, but usually irregular in outline. They consist of oblong grains and crystals (showing traces of pinacoids and domes) of colorless olivine, lying pellmell in a gray or colorless, finely fibrous groundmass. This is formed of patches of straight narrow fibers parallel over small areas, each small area extinguishing as a unit, but unlike those adjacent, where the fibers run in another direction. It was supposed at first that these thin colorless rods were a rather basic plagioclase, since they extinguish at various angles up to 20° with their long axes, and their polarization colors are grays and pale yellows. Close examination under high powers, however, revealed the fact that in many places there is no break in continuity between the fibers and distinct adjacent olivine crystals, and that in these cases both crystal and fibers extinguish simultaneously. They must, therefore, be referred to olivine, and the apparent oblique extinction is due to the fact that the fibers project obliquely from the surface of the olivine crystal, seemingly in the direction of a domal or prismatic plane. That they are rods and not plates (as in the preceding type of chondrules) is shown by their sections in certain places, where they present the appearance of small rounded grains. Such skeletal development is a not uncommon feature of olivine, as is well known.

Other porphyritic chondrules are seen in which olivine crystals and fragments are embedded in a fine-grained mosaic of olivine and enstatite grains. One peculiar ovoidal chondrule was observed, composed of a long, seemingly corroded, olivine

* Brezina, Ann. k. k. Nat. hist., Hofmuseums, x, 261, 1895.
† Tschermak, Mikr. Besch. d. Meteoriten, pl. x, 2.

crystal, surrounded by a mosaic of small grains of the same mineral. There were a few monosomatic chondrules of olivine, with approximately circular outline, but curiously and irregularly hollow, the interstices between the separate patches of olivine being filled with granular bronzite. Others again were found with monosomatic borders and portions of the interior of bronzite, containing olivine grains.

The crystals and fragments of bronzite and olivine offer no features of special interest. They are colorless, except where stained by ferruginous decomposition products, and are quite fresh, even the olivine showing no traces of serpentinization. Each mutually encloses the other, so that they were apparently crystallized at the same period. Both include small angular fragments of iron. Only a few crystals and fragments, which could be definitely referred to pyroxene, were observed. In one case two pyroxene fragments, giving oblique extinction, are enclosed in a patch of bronzite. A few grains which may be referred to plagioclase were found, one of these showing traces of twinning lamellæ.

Grains of nickel-iron are quite abundant. They are all small and angular and irregular in outline; and apparently generally later than either the olivine or bronzite, as they are xenomorphic toward these and occupy the interstices between them, and also include crystals and fragments of these minerals. At the same time, as we have seen, small particles of iron are included in these minerals.

The iron has suffered greatly from oxidation, being usually surrounded by yellow, or deep reddish-brown, translucent, doubly refracting, matter. This is probably limonite, since it answers to Pelikan's* description of limonite under the microscope, and since the analysis shows that there is no silica, above that necessary for the olivine, etc., to form a ferrous silicate, as it was suggested to be by Kunz and Weinschenk† in the case of the Washington, Kansas, meteorite. This ferruginous substance has penetrated all the crevices of the mass, being found in the interior of even the largest mineral grains, is seen in patches throughout all the sections, and is what gives the brown color to the mass.

A careful search revealed no grains of troilite, though the chemical analysis shows that about five per cent was probably present originally. It has possibly been entirely decomposed.

For the chemical analysis 25·2 grams were taken, of as fresh material as was available, with no crust attached. An attempt was first made on 13 grams to separate the nickel-iron by means of an electro-magnet. This proved to be a matter of

* Pelikan, Tsch. Min. Petr. Mitth., xiv, 5, 1895.

† Kunz and Weinschenk, Tsch. Min. Pet. Mitth., xii, 180, 1891.

great difficulty, on account of the very dense and compact texture, and after two days had been spent in successive separations under alcohol, and after analyses of the products had been partially completed, this method was abandoned.

Eggertz's iodine method* was finally employed and proved fairly satisfactory. It seems, however, very desirable that some method be devised for the determination of the separate amounts of Fe, Ni, Co, FeO, Fe_2O_3, NiO and CoO, which does not involve the use of either iodine solution or solutions of such salts as double mercury or copper, ammonium chlorides, whose employment involves considerable extra outlay of time and labor, and whose action on certain constituents of meteorites is not well known.† From a petrological, and indeed from a chemical and mineralogical, point of view, meteorites are analogous to terrestrial igneous rocks, and should be treated as such. In the analysis of terrestrial rocks the separation into soluble and insoluble portions has been long abandoned, except for certain special investigations, since the separations are never either constant or complete, and since they are generally unnecessary, because the microscope and methods of chemical calculation enable us to determine the mineral constitutents and their relative amounts with great precision.

It is evident, however, that a complete analysis of a stony meteorite by the ordinary methods of such analysis is not sufficient, since the metallic Fe, Ni and Co would be necessarily confounded with the oxides in the usual analytical processes, and their amounts—an important feature—would not be known, except roughly through the excess of oxygen.

A line of work which has suggested itself seems promising. This would consist in determining the total iron as Fe_2O_3, Fe and FeO as FeO, by the usual methods; determining the increase in weight by ignition in a current of oxygen, and the decrease in weight by ignition in a current of hydrogen,‡ both before and after ignition in oxygen. From these oxygen data and the amounts of Ni and Co as determined in the usual course, the separate amounts of the various metals and oxides of the iron group could, it would seem, be determined. Our knowledge of the action of oxygen and hydrogen upon the various silicates that go to make up meteorites is as yet far too small for employing such a method at present, and many experiments both as to the character and constancy of the action

* Blair's Iron Analysis, 3d ed., p. 79. My thanks are due to Prof. H. L. Wells for the reference to and description of this process.

† Cf. Cohen, Meteoritenkunde I, 1894, 13.

‡ Reduction in hydrogen has been proposed by Baumhauer and Rammelsberg, cf. Cohen, op. cit., p. 12. Baumhauer reports that at sufficiently low temperatures silicates and troilite are not acted on by hydrogen. For this suggestion I am partially indebted to Prof. Pirsson, with whom I discussed the matter

of these reagents on the silicates, troilite, etc., would have to be undertaken. The end in view would, however, seem to justify such an investigation.

The results of the several analyses are given below, the total analysis being calculated from the data furnished by the others. Part of the Cr_2O_3 was determined as chromite—this being assumed to have the simple composition $FeCr_2O_4$, the rest was precipitated as $PbCrO_4$. H_2O was determined as such in the total meteorite by Penfield's method,* and referred to the soluble portion. S and P_2O_5 were likewise determined in the total meteorite. The separation of soluble and insoluble silicates was effected in the residue from the solution of the nickel-iron by digestion on the water-bath for three hours with dilute HCl (1 : 5), and subsequent treatment with dilute KHO solution. The extra oxygen of the soluble portion† is that belonging to the ferric oxide of the limonite. It was estimated by calculating the amounts of olivine, augite and diopside present, and deducting the amount of FeO belonging to them from the total FeO.

The specific gravity was found to be 3·466 at 15°·5 C., taken with the balance, on a mass of 11 grams. The first approximate composition is:

Soluble	Nickel-iron	4·25
	Troilite	5·16
	Silicates	54·47
Insoluble	Chromite	0·87
	Silicates	35·25
		100·00

The analysis of the nickel-iron yielded:

Fe	89·67
Ni	10·01
Co	0·32
Cu	not det.
	100·00

The analyses of the soluble and insoluble portions, together with the calculated total composition, are as follows:

* This Journal, xlviii, 31, 1894.

† Total iron in this being determined as FeO.

	Soluble in HCl.	Insoluble in HCl.	Total.
SiO_2	21·34	56·44	33·11
TiO_2	----	not det.*	not det.*
Cr_2O_3	----	1·61	0·58
Al_2O_3	0·27	4·85	1·77
FeO	41·38	9·16	27·97
Fe	----	----	3·81
NiO	2·67	trace	1·77
Ni	----	----	0·43
CoO	trace	----	trace
Co	----	----	0·01
MnO	----	trace	trace
MgO	22·86	22·03	21·59
CaO	0·46	2·87	1·31
Na_2O	not det.	1·79	0·65
K_2O	not det.	0·77	0·28
H_2O	5·08	----	3·03
P_2O_5	0·62	----	0·37
S	3·15	----	1·88
Extra O	2·88	----	1·76
	100·71	99·52	100·32
Less O = S	1·57		0·92
	99·14		99·40

It is evident that the soluble portion is made up largely of olivine, with troilite and limonite, and small quantities of pyroxene and oxide of nickel; while the insoluble is chiefly bronzite, with accessory chromite, feldspar and augite. Calculation from the data furnished by the analyses shows that the mineralogical composition of the stone is approximately:

Nickel-iron	4·3
Troilite	5·2
Chromite	0·9
Schreibersite?	0·8
Olivine	30·2
Bronzite	23·6
Pyroxene	5·0
Oligoclase (Ab_5An_1)	6·6
Orthoclase	1·6
Limonite	20·2
Nickel oxide	1·6
	100·0

* Present in small amount.

In the above all the phosphorus is assumed to exist as schreibersite, soda and potash to belong to the feldspars, and the NiO to be the product of the oxidation of the nickel-iron. It will be evident that if, as seems certain from the microscopic examination, the limonite is derived entirely from the metallic iron, the amount of metallic Fe originally present was higher by some 12 per cent, and the nickel higher by 1·25 per cent. The nickel-iron present in the fresh stone would then have amounted to about 17·50. That the orthorhombic pyroxene is bronzite rather than enstatite is shown by its calculated composition, which is

SiO_2	56·8
MgO	32·6
FeO	10·6
	100·0

The pyroxene is largely diopside, with less than 10 per cent of the aluminous augite molecule. The plagioclase is an oligoclase of the composition Ab_5An_1. The orthoclase molecule probably also belongs with it, in which case it must have about the composition $Ab_5Or_1An_1$.

On the whole the stone seems to belong to a rather widespread group, and does not differ essentially from several that have been recently described from this continent; e. g., the Salt Lake City,* the Bluff,† the Beaver Creek,‡ and the Washington, Kansas,‖ meteorites.

* Dana and Penfield, This Journal, (3), xxxii, 226, 1886.
† Whitfield and Merrill, This Journal, (3), xxxvi, 113, 1888.
‡ Howell and Merrill, This Journal, (3), xlvii, 430, 1894.
‖ Kunz and Weinschenk, Tsch. Min. Petr. Mitth., xii, 177, 1891.

Locust, N. J. April 22, 1898.

ART. LVII.—*Comments on Bulletin No. 21. "Solar and Terrestrial Magnetism in their relations to Meteorology;"* by FRANK H. BIGELOW.

[Communicated by permission of the Chief of the Weather Bureau.]

COMPLYING with a suggestion by the editor of this Journal to set forth the leading conclusions contained in my Bulletin No. 21, recently published by the U. S. Weather Bureau, the following comments are made with the view of bringing out prominently the important features of the subject as now understood. Those who have been familiar with the general conditions of meteorology and terrestrial magnetism, as regards the explanation of the observed phenomena by means of current hypotheses, must be aware of the very unsatisfactory state of these subjects in many particulars. In meteorology the widely accepted view of the generation of cyclones was based upon the vertical convection currents from local centers, which Professor Ferrel used as his working hypothesis, in his attempt to construct the laws of observed circulation. But the revolt from this position has become general, and it is not too much to say in advance that the outcome of our cloud observations greatly strengthens the position of those who claim that a new theory must be constructed. In terrestrial magnetism affairs were even worse, because there has been only the vaguest approach to a definite conception of the laws likely to account for the diurnal and annual periods, or the disturbances of the elements, to say nothing of the secular variation and the undoubted synchronism observed between the solar and the terrestrial phenomena. It has long been my conviction that these entire subjects needed a thorough overhauling, and that this involved the cutting loose from several opinions generally received in scientific circles. To thus separate from common conceptions involved considerable risk from two sources, (1) lest it be impossible to secure a scientific demonstration of a clear theory, while running counter to public opinion, and (2) the impracticability of publishing in sufficient detail the data involved in the discussion. For it must be admitted that magnetism in its relation to meteorology is a paradise for all sorts of pseudo-scientists, and that the entire field is cumbered with unproved and pretentious propositions. Nevertheless it must also be noted that when an investigator passes away from the observations of precision afforded by astronomy, geodesy and physical laboratory experiments generally, to the fitful measures made at the bottom of the atmosphere, which represent complex stream lines, and also the resultants of many compo-

nent forces, it is only fair to bear in mind that we have no better material than this to work with. The observations of meteorology and magnetism are very hard to handle with sufficient precision to give perfect laws, and critics should always remember, (1) that laws which are even approximately made out become very valuable for further advances, and (2) that every criticism ought to make sure that the author's position is not only understood, but also that the critic knows more about the point in hand than the investigator himself.

Taking up now the details of Bulletin No. 21, it will be seen that an attempt has been made to overthrow two positions held in terrestrial magnetism, (1) that the sun is not a magnetic body because it is too hot, and (2) that the variations of the terrestrial magnetic field can be accounted for by electric currents in the cirrus cloud regions; also a promise is made to examine the meteorological problem in a forthcoming report on the International cloud observations. Before recapitulating the arguments used in sustaining these two propositions, it is to be observed that the method of handling the observations is the simplest possible, as explained in Bulletin No. 2, of the Weather Bureau, 1892. It consists in assigning a normal field at a given station, and then subtracting this from the observed field, whereby a system of components is obtained which go to make up the forces that deflect the actual field from its normal position. Three rectangular elements are combined into the corresponding vectors acting in space, at a given time, and the collection of these together builds up the total vector system, which can be studied by itself and on its own merits. This plan has recently been advocated by von Bezold, Zur Theorie des Erdmagnetismus, 1897; the coming Conference of Magneticians to meet at Bristol, England, Sept. 7–14, 1898, will discuss the same principle in different aspects; and indeed its use is so obviously advantageous that what astronomers have long been doing is now applied to terrestrial magnetism and meteorology. By computing the vector systems belonging respectively to the daily means and the hourly means, as published, two different auxiliary fields have been disentangled, which added to the normal field give the actual field as observed. These two fields are the bases of our discussions and conclusions, and they have characteristics which seem to indicate a simple interpretation of the entire range of phenomena.

The temperature argument.—It was easy to conclude that because an ordinary magnet loses its magnetic force under high temperature, therefore the sun *must* be non-magnetic; and it is so difficult to disprove this argument, that this opinion is not only widespread, but tenaciously held as a canon of modern science. Yet it has been treated too long a bogey to

frighten off serious attacks upon its validity, and in my judgment it has done great injury to the advancement of this branch of science. There are several good grounds for distrusting its truth, and it may be stated that expert opinion is gradually coming to the general conclusion that the sun, the earth and the moon, are three magnetic as well as gravitating bodies, and that thus several unexplained gaps in science become readily filled. It is plain that while the earth is hot in the interior a moderately strong magnetic field is sustained around it. This fact alone makes the earth, and not a steel magnet, the analogue of the sun. After the evidence brought together by van Bebber in Witterungskunde, by Bulletin No. 21, and also by many other writers, it is quite impossible not to accept the conclusion that the variation of the sun's forces, as shown in the state of its visible surface, the spots, the prominences and faculæ, and the corona, are synchronous with changes in all the elements of the earth's atmosphere. We are therefore confined to two lines of thought, either to show that there are variations in the sun's electromagnetic field, that is in its insolation, or else to admit that the sun possesses a true magnetic field, which embraces the earth in its operations. Now there is at present no evidence whatever that the sunlight field has any variable intensity, and on the other hand Bulletin No. 21 shows that the earth is immersed in an external magnetic field of such a direction and strength as to make the inference necessary that its seat is in the sun. Else if one admits the above-mentioned synchronism between solar and terrestrial elements, it will be necessary to assert that the earth's changes are sufficiently strong to disturb the sun's state as observed, which is of course absurd.

That the earth is plunged in a variable external magnetic field is so simply proved as to be quite beyond controversy. On Charts 17 and 18 is seen a collection of the traces of the horizontal forces from the two hemispheres. They exhibit the phenomenon that the horizontal force rises and falls in strength simultaneously over the entire earth, which is the common and persistent fact, just as much as it is true that a body falls towards the center of the earth by gravitation. Likewise it can be shown throughout the observations that when the horizontal force diminishes, the vertical force increases its strength, as generally and as continuously. Charts 6, 7, 8, 12, 36, 37, 38, 39, exhibit in detail the effects upon a field surrounding a magnet, when immersed in an external field of alternately greater and less strength than its normal field. The closed curves are expanded or contracted on each side of the mean, and this involves such changes in the horizontal and vertical forces as are found to be taking place throughout the earth's field. I recommend that criticism begin at this point, and that its consequences be candidly followed out.

The third line of argument tending to show that the sun though hot is magnetic is found in the compilation of testimony contained in Chapter 6. There it is shown that the rifts seen in coronas of the sun during eclipses closely fit the structure of a spherical magnet whose lines are viewed in projection on a plane, and we need only to suppose that the magnetic lines of the sun tend to arrange the surrounding material of its envelopes in the same way that a steel magnet disposes iron filings in its neighborhood. The period of rotation for an assumed solar nucleus is such that at least three coronas seem to correspond to one and the same model, when located mechanically by astronomical coördinates. The distribution of the sun spots in the adopted period of 26·68 days, in the two hemispheres, gives back the characteristic type curve, in its direct and inverse forms, pointing at least to some subtle and perhaps unsuspected law of solar operation. The Chandler long period variation of the position of the earth's axis of rotation is in so close agreement with the well known 11-year sun spot period as to demand complete investigation. Finally, the peculiar phenomenon of inversion of the type curve semi-annually in all its characteristics, constitutes another delicate test of the general fact of the magnetization of the sun, since its turning points are precisely in harmony with the position of the sun's axis and nodes, so that an accidental coincidence is quite impossible. Such a long series of phenomena, as those just enumerated, if not proving that the sun is a magnet, at least demands the respectful attention of those who still adhere to the high temperature argument.

Electric currents in the cirrus region.—It is probable that the only real strength behind the hypothesis, that a system of electric currents in the cirrus level is the cause of the variations of the earth's magnetic field as observed at the surface, is due to the process of exclusion by which the direct action of the sun as a magnet, the Faraday idea of the magnetic action of the oxygen of the atmosphere under differences of heat, and also the thermoelectric currents of the ground, were thrown out of the discussion. Passing over the last two entirely, it is quite clear that insuperable difficulties stand against the electric current theory. These are supposed to originate in the general motions of the atmosphere, due primarily to convection over the hemisphere, and hence they depend upon meteorological phenomena. But why assign them to the cirrus region, except on the philosopher's plan of always keeping the causes just beyond reach of criticism. In fact the cirrus region is known to be about the best behaved stratum in the atmosphere, since it is entirely exempt from all the minor variations of temperature felt near the ground;

but this stratum sails eastward serenely while magnetic theory demands that it should move westward; and also no physical cause has been proposed to show why electric currents should especially originate at that level. There would be very much more probability of the desired variations occurring in the strato-cumulus or the alto-cumulus levels, if these had been chosen for the purpose.

But there are two main lines of argument against the theory, which are really serious. One is that the magnetic field demands a cosmical cause, and the other is that this field requires shorter vibrations, and also longer sustained states than the meteorological conditions of the atmosphere can furnish. Regarding the first, as already mentioned, it is evident that the magnetic field of the earth is changed as a whole in every part of the globe instantly and synchronously; also these perpetual fluctuations can readily be grouped in a solar period. Now meteorological conditions are very local affairs, and we have no evidence of *rapid short* variations occurring all over the world at the same time. If the deflecting forces of the magnetic field are spread out in long tabulations such as shown on pages 46, 47, 51–56, extending through several years, it is to be seen by mere inspection that the changes are periodic, and I made out the period to be 26·68 days, which corresponds closely with the rotation of the sun at its equatorial belt, as measured by the motion of the sun spots. Furthermore the direction of the deflecting vectors themselves is such, that a field of magnetic force is directed upon the earth, positive north and negative south of the ecliptic; this is also the direction from which the great disturbances come as illustrated on pages 72–78; this period and its direction is persistent through half a century as indicated on pages 100–102; it is subject to two peculiarities, namely that the field is of such a configuration at the earth's surface as to correspond to a permeable shell placed within a uniform field, pages 61–72; and it is as a whole subject to a peculiar inversion in the four parts of the orbit of the earth about the sun, indicated on pages 106–107. It appears that such phenomena are precisely adapted to the explanation offered by the Bulletin, namely that the earth is in an external field sustained by the sun, and on the other hand one is driven to conclude that the electric currents of the cirrus region are powerless to produce such effects. Of course we do not deny the existence of electric currents entirely, since these must exist in all variable magnetic fields.

The other difficulty consists in the proposition that the earth is subject to such long sustained general states, extending over years, as to preclude the electric current theory, though even these too may well be included as a part of the effects of a solar

magnetic field. Thus we have undoubted evidence that the entire magnetic and meteorological systems go through 11-year fluctuations, synchronous with the sun spots which register the solar conditions. These are indicated on pages 121–125, where the data is greatly abbreviated from the compilations in our hands. It may be said in passing that the brief abstract before us does but scant justice to the material of the research. This, however, it was very difficult to publish in its entirety, and scientists must feel at a real disadvantage in estimating the soundness of some of our conclusions, unless they go through the great labor of reproducing similar data for themselves. We might give much more evidence from several other sources in favor of the long period variations, but this subject is already well known, and our only contention here is that the electric current theory of the upper atmosphere looks like transposing an effect into an efficient cause, unless it is proposed to make the earth wag the sun to fill out the explanations.

I have made the position prominent in the Bulletin that the earth is plunged in two external magnetic fields, because we have two distinct vector systems which demand that interpretation. The first was concerned with the long and short aperiodic terms, the Eschenhagen very quick variations, the disturbances, and the long range fluctuations, as well as the period corresponding with the rotation of the sun on its axis. The second is wholly confined to the diurnal variations of the needle and the annual period within these elements. This second field is illustrated on pages 85–92, and it is characterized by the phenomenon of magnetic refraction at the surface of the earth, and by the existence of sets of couples, which also forces us to the conclusion that the earth has a permeable shell, and that the field itself is associated with the polar radiations of light. This vector system changes with the year northward and southward, and always follows the declination of the sun, but the material for showing that is entirely omitted from the Bulletin. At any rate the two vector systems each indicate that the outer shell of the earth is more permeable to these external fields than the entire body of the earth itself.

We have at this point broken with current opinion, and that too, curiously, in two opposite directions. It is objected that the electromagnetic field cannot act as a steady field because it is too rapid. We reply that it is so rapid that our exploring magnets by their inertia cannot pick up the changes, and that they register as if the field were steady. On the other hand it is objected that the common polar magnetic field is too quiet, has no currents of electricity, and therefore no power to produce changes of temperature by transmitting energy. But we quote some propositions from Heaviside's papers to show that

an unsteady polar field transmits energy accompanied by transient currents of electricity, and that half this energy goes into setting up the new state of the field and half into heat. Furthermore the most probable explanation of magnetic lines of force is that they are constructed of electric currents, in rotation around the axis of the vortex tubes stretching from the positive to the negative parts of the field. The whole agency being dynamic, we can easily conceive that there is a continuous effect upon the earth's atmosphere, either by direct additions of energy, or by modifying terrestrial radiations, since the solar field is perpetually in vibration.

Evidently there is an immense mass of testimony to show that something of the kind is going on continuously. For we find that all the characteristics of the magnetic periods are reproduced in the temperatures and pressures of the northwest; also in the location of the storm tracks from year to year, as given in compressed form on pages 108–130. The three elements, magnetic field, temperature and pressure, were all handled in precisely the same way, at first tentatively seeking to discover the law of inversion, which was forced upon our attention by trying to carry the type curve through the changes shown on the daily weather maps. As the outcome of much work we are in this position: The temperature and the pressure certainly must and do vary together, but the magnetic field on the average gives us curves agreeing with either of these elements, just as exactly as they do with each other; our final compilations being strictly mechanical along the lines of the general law. It must be remarked that in comparing the curves of the individual periods with each other there is much looseness and irregularity, so that even a friendly investigator may superficially conclude that I have been tempted to force my data to my conclusions, while an unsympathetic critic may find himself willing to throw out the entire subject on the ground of individual discrepancy. Neither would be right in such a decision, for there is no possible ground of intimating more than that I may have been mistaken in my judgments. Still, to guard against this possible issue, the work has been done over and over again in at least four combinations, in such a way that it would be impossible to remember former assignments of direct or inverse type. In all cases about 75 per cent of the curves get the same interpretation, and this was true for one of my assistants as well as for myself. There is some need of practice and aptitude in dealing with such curves as these, but perhaps nothing better can be done with the subject-matter itself at present. Even in such simple curves as the diurnal variations of the magnetic forces, wild discrepancies are encountered; in the case of our nine-crested curve,

seated in the unsteady sun for a base, we must expect to deal with just such fluttering curves as are herein described. At least my interpretation of the many hundred curves reduced to the 26·68 day period, is worthy of careful consideration.

It will be noticed that I terminated my discussion of the cause of the phenomenon, and the pure physics involved in the inversion of the type curve, rather abruptly, after showing its relations to the magnetic field of the sun in the several parts of the orbit. It is clear that the components are such as to produce opposite effects, the field lying now across and again along the orbit, the earth driving through it at the rate of a million miles a day. After long consideration of the complicated conditions involved, the three axial motions and the complex computations required, the lack of our knowledge about atmospheric transformations of energy and radiations, I conclude that the problem is beyond my powers for the time being. This is also the more the case because of the total lack of magnetic observations in the northwest of the United States and western Canada, upon which to do definite work. The European data are good, but Europe is too far away, and unfortunately it is located in the hollow of the external field, belt M, Chart 10, where the exflected and inflected branches come together, and where the forces are very fluctuating in their directions. To make matters worse, just at this time our American observations have been practically extinguished by the encroachments of the city electric trolley lines, and the material is now rendered useless for these refined purposes. The only alternative seems to be to remove the observatories far into the country, to some spot away from the advance of the improvements of civilization. However, in view of the unusual interest and importance of the material contained in Bulletin No. 21, even if only a portion of it sustains final criticism, it is evident that the duty of American Science is to set up some first class magnetic observatories, and to run them for a term of years, till we can get good data to work upon in the pure physics required. It is hoped that this paper will be considered a valid plea to bring this about before very long.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On Electrolytic Dissociation and Osmotic Pressure.*—It has been already shown by Traube that if N gram-molecules be present in one liter of the co-volume* of any liquid, the pressure will equal 22·38 N atmospheres. If now we suppose water and a sugar-solution separated by a semi-permeable membrane, the water containing N molecules in each liter of its co-volume and the sugar solution N molecules of water to ν molecules of sugar, the author considers that the ν sugar molecules may enter into unstable union with a molecules of water, and the number of water molecules entering the membrane from opposite sides will be in the ratio $N : (N - a\nu)$; thus producing the observed contraction in volume. Consequently the pressure on the side of the solution will be less than on the side of the water by $22{\cdot}38\, a\nu$ atmospheres. If a be unity, the pressure observed is in accord with the theory of Van't Hoff; so that it follows that the decrease of pressure on the side of the solution, due to the combination of the water with the dissolved substance, is the osmotic pressure. It has been shown by Poynting† that if this origin be assigned to the osmotic pressure, we can at once account for most of the observed relations. Some exceptions have been noted in the case of electrolytes. But these may be explained by variations in the value of a; so that it is not necessary to assume electrolytic dissociation in these cases.—*Ann. Phys. Chem.*, II, lxii, 490–506, October, 1897. G. F. B.

2. *On a New Substance for increasing the Angle of Rotation.*—In his investigations on the malic acids Walden has made much use of their optical rotation. And since this rotation is slight, he has sought to increase its amount without changing its direction. The effect of oxygen salts of boron in this particular, had been observed by Biot and Pasteur; and that of the oxy-salts of arsenic, antimony, molybdenum and tungsten, by Gernez. But their action was feeble. In the salts of uranyl, however, the author found substances fulfilling all requirements. Either uranyl acetate or nitrate may be used, but the latter is preferable because of its greater solubility. To the solution to be examined, potassium hydrate solution is first added and then the solution of uranyl nitrate, the clear yellow solution thence resulting being examined in the polariscope in sodium light. The potassium hydrate solution contained 10·8 grams and the uranyl nitrate solution 40 grams to the 100^{cc}. Using *l*-malic acid solution alone (13 grams in 100^{cc}) the rotation in a tube 2 decimeters long was only $-0{\cdot}01°$ and the specific rotatory power $-0{\cdot}77°$. When to 1^{cc} of the malic acid solution, 2^{cc} of the potassium hydrate solution was

* See this Journal, IV, iii, 479, June, 1897.
† Phil. Mag., V, xlii, 289, 1896.

added and the whole diluted with 20^{cc} water, the specific rotatory power was $-3{\cdot}0°$. With 1^{cc} malic acid solution and 5^{cc} uranyl nitrate solution (diluted with water to 20^{cc}) the value of $[\alpha]_D$ was $-11°$. With 1^{cc} malic acid solution, $\frac{1}{2}$^{cc} KOH solution and 1^{cc} uranyl nitrate solution, diluted to 20^{cc}, the value of $[\alpha]_D$ rose to $-139°$. And when to 1^{cc} of the solution of malic acid, 2^{cc} KOH solution and 1$\frac{1}{2}$^{cc} uranyl nitrate solution were added, and diluted to 20^{cc}, $[\alpha]_D$ reached $-475°$. This maximum was attained when to 1 molecule malic acid about 4 molecules of KOH and from 1–4 molecules of uranyl nitrate was used; the value then being more than five hundred times greater than the value given by the malic acid solution alone. Similar results were obtained with tartaric acid and its mono-methyl ether; with quinic acid and with *l*-mandelic acid; though in a less degree. The inactivity of *i*-malic, *i*-mandelic and mesotartaric acid was not altered by the uranyl salt. Acids such as *d*-chlorsuccinic, *l*-bromsuccinic and *d*-amylacetic, which contains no free hydroxyl group, show no increase of rotatory power on adding the uranyl salt. The author summarizes his results as follows: (1) Alkaline solutions of uranyl salts produce both in aqueous and alcoholic solutions, a marked increase of rotatory power in the case of optically active acids; (2) this increase is conditioned upon the presence in the acid of a free hydroxyl group; and (3) it reaches its maximum when to one molecule of the oxacid (for example oxydicarbonic acid) at least one molecule of uranyl salt is added, together with the quantity of alkali required to neutralize the carboxyl groups and also the acid contained in the uranyl salt (i. e. about 4 molecules in all).—*Ber. Berl. Chem. Ges.*, xxx, 2889–2895, December, 1897. G. F. B.

3. *On the Influence of the Silent Discharge on Atmospheric Air.*—A series of experiments has been made by Shenstone and Evans on the influence exerted upon atmospheric air by the silent electric discharge. Their conclusions are as follows: (1) Oxygen diluted by nitrogen yields a higher proportion of ozone when submitted to the influence of the silent discharge under given conditions, than pure oxygen; the proportion of oxygen ozonized may be as high as 98 per cent. (2) If the process be not pressed too far, no nitrogen peroxide will make its appearance. (3) The presence of water vapor is very favorable to the production of a high yield of ozone and retards the appearance of nitrogen peroxide. (4) At a certain stage in the process, depending on the amount of vapor present and probably also on the temperature of the gas, nitrogen peroxide is formed; its appearance being almost immediately followed by a rapid disappearance of the ozone, this in its turn resulting in the destruction of most of the peroxide. (5) That, as Andrews has stated, the presence of a trace of nitrogen peroxide renders it impossible to convert oxygen into ozone by means of the silent electric discharge. And (6) nitrogen peroxide and ozone when moist do not mutually destroy each other at 0°, or do so at a very slow rate, unless they are under the

influence of the silent discharge.—*J. Chem. Soc.*, lxxiii, 246–254, April, 1898. G. F. B.

4. *On the Action of Hydrogen on Sulphuric Acid.*—It has been observed by BERTHELOT that on passing a slow current of hydrogen through concentrated sulphuric acid for an hour at the ordinary temperature, there is no sulphurous oxide formed. If however the contact between the hydrogen and the acid be much prolonged, the gas is finally absorbed and a reduction of the acid takes place. Dilute sulphuric acid is not reduced by hydrogen. At the temperature of 250°, when the acid is concentrated, the reduction takes place somewhat rapidly, particularly in presence of a considerable excess of acid. When mixtures of oxygen and hydrogen are left in contact with sulphuric acid either at the ordinary temperature or at 250° both gases are absorbed. The rate of absorption of hydrogen however is the same as in the absence of oxygen, while the oxygen is absorbed in consequence of its combination with the sulphurous oxide formed by the reduction. If the hydrogen and the sulphurous oxide be dry, they do not act on each other either at 100° or at 280°. The reduction of concentrated sulphuric acid by hydrogen is an exothermic reaction, developing +15·1 Cal., this value being increased to +30·1 Cal. when the sulphuric acid is in large excess, owing to the heat of hydration. In the case of dilute sulphuric acid however the reaction would be endothermic.—*C. R.*, cxxv, 743–746, November, 1897. G. F. B.

5. *On the Preparation of dry Hydrogen cyanide and Carbon monoxide.*—While it is evident that both hydrogen cyanide and carbon monoxide may be formed by the action of sulphuric acid or potassium cyanide, yet WADE and PANTING have now shown for the first time that a practically quantitative yield of either product can be obtained at will by varying suitably the concentration of the acid. When the cyanide is distilled with the dilute acid, dilute hydrogen cyanide passes over; but when equal volumes of sulphuric acid and water are used, the distillate contains only small quantities of aqueous vapor; and this can be removed by passing it over warm calcium chloride. As the sulphuric acid becomes stronger a certain amount of carbon monoxide is formed, the quantity of the gas increasing with the concentration, while the hydrogen cyanide decreases. So that at last when sulphuric acid of the ordinary commercial strength acts on the cyanide nearly pure carbon monoxide is evolved in almost theoretical quantity. Thus when a mixture of equal volumes sulphuric acid and water (100^{cc} of each) is allowed to drop on 100 grams 98 per cent cyanide in a capacious flask, provided with U-tubes filled with calcium chloride and with condensing tubes cooled to −10°, about 40 grams (58^{cc}) of practically pure hydrogen cyanide is obtained; which on rectification from phosphorus pentoxide boils at 26·2°–26·3°; the average yield being 38·5 grams, theory requiring 40·8 grams. On the other hand, when 50 grams of cyanide are treated with cold concentrated sulphuric acid, 14

to 16 liters carbon monoxide is obtained, the calculated quantity being 17. At first sight, it might appear that the production of the carbon monoxide is simply a matter of hydrolysis and dehydration, the hydrogen cyanide being converted into formic acid and this into carbon monoxide:

$$KCN + (H_2SO_4)_2 + H_2O = KHSO_4 + NH_4HSO_4 + CO$$

But since the result is equally well obtained by a mixture of two volumes of ordinary with one volume of Nordhausen acid, evidently water can play no part. Moreover hydrogen potassium sulphate may be used, a mixture of the dry salt with dry potassium cyanide evolving when heated to 230°–250°, anhydrous hydrogen cyanide, while a large amount of carbon monoxide is continually produced, and the residue smells strongly of ammonia:

$$KCN + (HKSO_4)_2 = K_2SO_4 + K_2S_2O_7 + CO + NH_3$$
$$(KCN)_2 + (KHSO_4)_6 = (K_2SO_4)_3 + (K_2S_2O_7)_2 + (CO)_2 + (NH_4)_2SO_4$$

J. Chem. Soc., lxxiii, 255–258, April, 1898. G. F. B.

6. *On the Electrolytic production of Iodoform.*—Very satisfactory results have been obtained by Foerster and Meves in the preparation of iodoform by means of electrolysis, the yield being 80 per cent of the potassium iodide employed. An ordinary battery jar closed with a plate of india rubber, contained three platinum plates as electrodes, the middle one, about 85 sq. cm. in area, being the anode and the cathodes being wrapped in parchment paper. Between the electrodes were two entrance tubes for gases and an exit-tube. A copper and a gas voltameter were in the circuit. The charge consisted of 400^{cc} of a solution containing 60 grams potassium iodide, 20 grams sodium carbonate and 80 grams alcohol, the whole being kept at 65° by means of a water-bath. The current density was 2 amperes per sq. dm. and to obtain this two volts were required. The iodoform was removed every 8 ampere hours and the corresponding amount of potassium iodide and 20^{cc} alcohol was added. The reaction is

$$C_2H_6O + H_2O + I_{10} = CHI_3 + (HI)_7 + CO_2$$

A slow current of CO_2 is passed through the cell to take up the KOH formed at the cathode.—*J. pr. Ch.*, lvi, 353–363, December, 1897. G. F. B.

7. *Das physikalisch-chemische Institut der Universität Leipzig* und die Feier seiner Eröffnung am 3 Januar, 1898. Von Prof. Dr. W. Ostwald, Direktor des Instituts, pp. 44. Leipzig, 1898. (Engelmann.)—A description of the new Institute with Prof. Ostwald's admirable opening address.

8. *A Manual of Quantitative Chemical Analysis;* by E. F. Ladd, B. S. 12mo, pp. vi, 82. New York, 1898. (John Wiley & Sons.)—This little book contains selected methods designed for the beginner in quantitative analysis, "not the ones that would always give the most reliable results in professional work," but "those that represent principles that will aid in developing the reasoning power of the student." For this purpose a set of questions is given at the end of each method. The methods seem well chosen and the processes are clearly described.

9. *Fluorescence and Actinic Electricity.*—In order to connect together by a reasonable hypothesis the various phenomena of luminescence, E. Wiedemann and G. C. Schmidt have suggested that in many cases the absorbed light energy in the ions of broken up molecules may determine when the molecules are again formed—the phenomena of fluorescence and phosphorescence. G. C. Schmidt has taken up the subject again in order to see whether the three phenomena *ionisirung*, *fluorescenz* and *actinoelectricität* are connected. He concludes from his researches that

(1) Ionizing and fluorescence do not stand in immediate connection with light-electric sensitiveness.

(2) In the case of elementary solid bodies and solid solutions fluorescence and actino-electric phenomena are not related.

(3) With the exception of uranium and thorium and their combinations, all bodies so far as they absorb ultra-violet light are light-electric sensitive at high potentials.

(4) Uranium and thorium and their combinations dissipate positive electricity as well as negative.

(5) The solid solutions of light-electric sensitive substances are also light-electric sensitive.

(6) Solid bodies which are light-electric sensitive preserve this property in their solid solutions.

(7) The solid solutions which hold uranium salts are not light-electric sensitive. They dissipate, however, equally well positive and negative electricity in the dark.

(8) In those bodies, which after being submitted to cathode rays become intensely thermo-luminescent when heated, negative electricity is strongly dissipated.— *Wied. Ann.*, No. 4, pp. 708–724, 1898. J. T.

10. *New Method of determining the inclination and horizontal intensity of the earth's magnetism.*—Various attempts have been made to perfect the method of obtaining these quantities by means of the earth inductor, but the method has not been considered a precise one. G. Meyer describes an earth inductor which is kept in continuous rotation, and the neutral condition in which there is no current is determined by means of a telephone or capillary electrometer. The inclination can be measured to one-tenth of a degree. The instrument is especially fit for transportation, since no galvanometer is used.— *Wied. Ann.*, No. 4, pp. 742–751, 1898. J. T.

11. *Röntgen Rays and ordinary light.*—Sir G. Stokes and Professor J. J. Thomson have lately developed the theory that these rays are evidence of electromagnetic impulses. Lord Rayleigh criticises this contention and is surprised by the theory "that the Röntgen rays are not waves of very short wave length but impulses," and asks if short waves are inadmissible why are not longer waves also, and what becomes of Fourier's theorem according to which any disturbance can be analyzed into regular waves. Lord Rayleigh refers to a paper in which he proved that

white light may be supposed to have the very constitution now ascribed to the Röntgen radiation, except that the impulse would have to be less condensed. The absence of refraction and diffraction of these rays could therefore be attributed to the extreme shortness of their waves.—*Nature*, April 28, 1898. J. T.

12. *A Method of Measuring the Pressure at Any Point on a Structure, due to wind blowing against that Structure*, vol. viii, No. 1, of the Transactions of the Acad. of Science of St. Louis; by FRANCIS E. NIPHER.—This paper describes a collecting device which is unaffected by wind, but responds to any change in pressure due to wind. When the collector is held in wind in the free air, the gauge with which it is connected shows no effect, but it responds at once if the collector is sheltered by the hand, or if the hand be held to leeward of the collector.

The author has also checked the device by determining either directly or by interpolation the pressure at 108 points on the front and an equal number of points on the back of a pressure board having an area of 3x4 feet. The results check to within about one per cent., with the simultaneous measurements, by a spring balance, of the force required to hold the pressure board in position. The author concludes that the instrument may be used in determining the distribution of pressures over large and important structures, about which little is at present known.

The experiments were made from the roof of a railway car, at speeds of 54 miles per hour and less.

II. GEOLOGY AND MINERALOGY.

1. *Geological Survey of New Jersey. The Physical Geography of New Jersey;* by ROLLIN D. SALISBURY, with appendix by CORNELIUS C. VERMEULE, Vol. IV of the Final Report of the State Geologist, pp. 1–200, relief map. Plates i–xv with extras 24 in all, figures in text 1–37, 1898.—Professor Salisbury has shown in this report the intimate relationship existing between the physical geographical features of a region and the geological history it has undergone in the past. Its mountains, valleys, ridges, plains, lakes and rivers, are traced to their origins in the original geological formation underlying the surface, and their gradation, and the distribution of the derived materials to form new sheets of geological deposits. The guidance of the course of changes by the differential uplifts and submergences and emergences, and by the surface contours and relative hardness of the rocks is traced; and thus the successive stages in the history of the region are portrayed. The text is fully illustrated by profiles and illustrations of landscape. A large colored profile map of the state accompanies the report, which was prepared under Mr. Vermeule's supervision. "It is based upon the topographical survey, and is therefore an accurate picture of the surface relief. . . . A leading object in the publication of the map has been to put it in every school-house in the state as

an aid in the study of geography," and to stimulate inquiry into the origin of the topographic forms so graphically illustrated. Mr. Vermeule's appendix consists of valuable statistical tables on topography and magnetism, etc. H. S. W.

2. *The Cretaceous of Athabasca River;* by J. B. TYRRELL. (Ottawa Naturalist, vol. xii, No. 2, pp. 37–41.)—Mr. Tyrrell gives an abstract of the results of his explorations of the geology of the Athabasca region west of Hudson Bay. The study of the fossils collected has led him to modify the classification of the Cretaceous reported by Mr. McConnell as follows, viz:

"The paleontological evidence thus appears to show that it is necessary to modify Mr. McConnell's correlation of the Cretaceous of the Athabasca River to the extent of taking all the beds below the base of the Pelican Shales out of the Colorado Group, and of grouping together the Grand Rapid Sandstone, the Clearwater Shales, and the "Tar Sands" as one formation. This is a marine formation, stratigraphically equivalent to the Dakota, the fossils of which are practically the same throughout, and although no corresponding marine fossils are known elsewhere in the west, it appears to represent the marine conditions of the Dakota Period.

3. *The Mineral Resources of the United States for* 1896; by DAVID T. DAY.—Part V of the Eighteenth Annual Report of the United States Geological Survey, 1896–97 (Charles D. Walcott, Director) has recently been distributed. This promptness of publication, which we have noticed in regard to the earlier issues of the same work, deserves high commendation and enhances much the value of the material here brought together. This report is in two volumes, the first of which includes metallic products and coal; the second non-metallic products (except coal). The work has been carried on in the same lines as hitherto and includes contributions from a considerable number of workers. It is impossible to do more here than call general attention to it and indeed those interested are too well aware of its value to require more than this.

4. *Artificial Production of Diamond in Silicates corresponding to the Actual Mode of Occurrence in South Africa.*—The following abstract of an important paper by DR. I. FRIEDLÄNDER is quoted from the last number of the Geological Magazine. "In the recent diamond-making experiments of M. Moissan, fused iron rich in carbon was allowed to cool in such a way that the separation of the excess of carbon took place under pressure, and it was thought that a high pressure was necessary to the success which had been attained. It is now known that the necessary pressure is not very high, for microscopic diamonds have been found as normal constituents of ordinary cast iron. In South Africa no iron is present in the metallic state in the diamond-bearing rock, although it is largely present as a chemical constituent of the stony matter. Hence, in regarding Moissan's method as being possibly identical with the one by which the South

African diamonds had been formed, it was necessary to surmise that the crystals, after formation in the molten iron at some great depth below the earth's surface, had floated into the molten silicate-material above. It was, however, soon pointed out that the diamond-bearing rock, if in a state of fusion at small pressure, dissolves any diamonds contained in it."

Dr. Friedländer fused a small piece of olivine, a centimeter in diameter, by means of a gas-blowpipe, kept the upper portion in the molten state for some time by playing upon it with the flame, and stirred it with a little rod of graphite. After solidification the silicate was found to contain a vast number of microscopic crystals, but only in the part which had been in contact with the carbon. These Dr. Friedländer has subjected to a careful examination. They are octahedral or tetrahedral in form, are unattacked by hydrofluoric and sulphuric acids, have a high refractive index, sink slowly in methylene-iodide, burn away when heated in a current of oxygen, and are unaltered if heated in a current of carbonic acid: the stony matter containing them scratches corundum. Hence Dr. Friedländer infers that they are diamond, and that the South African diamond may have been actually formed, as already suggested, by the action of a molten silicate, such as olivine, on graphite: carbonaceous shales are interrupted by the diamond-bearing rock, and numerous fragments of the shale, much altered, are found enclosed in the rock itself. The paper is illustrated with seven micro-photographs.

5. *Contribution to the Petrography of the Boston Basin;* by T. G. White (Proc. Boston Soc. Nat. Hist., vol. xxviii, 117–156, 1897).—This article contains the results of a study under the microscope of the petrographic characters of the complex of rocks occurring in the Boston Basin district, especially those of igneous types, and will be found of interest and service to those engaged in the study of the local geology of that region. L. V. P.

III. Botany.

1. Mr. Walter Gardiner, of Clare College, Cambridge, continues in the *Proceedings of the Royal Society*, for Oct. 29th, his researches into *the structure of the cell-wall*, with special reference to the mode of communication between cells. In 1883, Mr. Gardiner pointed out the simple methods of demonstrating protoplasmic intercommunication in plants, and opened up a plain path in which he has had many followers. It became evident early in the minute study of this subject that the lines of communication were by no means as simple as were at first naturally thought. Improved methods of staining brought out new features, and these suggestions led to still further advance. During all this period Mr. Gardiner has devoted much time to the improvement of methods, and he now publishes a preliminary paper on his latest technique. In brief, the present method is as follows: after causing the cell-walls to swell by any one or all three of the agents usually employed, namely, picric acid, zinc chloride, or

sulphuric acid, he uses Kolossow's reagent, commonly described as osmic-acid-uranium-nitrate, as a fixative, and then stains with safranin or its equivalent. As a preservative he has had excellent results with thymol water. For details and for the important inferences, the reader is referred to the paper itself. The paper indicates the magnitude of the work still to be done in this direction, and suggests well-tried methods for the work. The most interesting generalization in the paper is that in regard to the sieve-cells, which are regarded by the author as presenting, on the whole, but slight differences from certain other active elements. G. L. G.

2. *The Phytogeography of Nebraska: I. General Survey;* by R. Pound, Ph.D., Director of the Botanical Survey of Nebraska, and F. E. Clements, A.M., Assistant Instructor in Botany, University of Nebraska. Lincoln, Nebraska, 1898. (Jacob North & Co.)—This interesting work is a substantial contribution to our knowledge of North American plants. While making themselves familiar with the Flora of Nebraska, the authors undertook the serious task of examining the species with relation to the surroundings. The results of their exhaustive study are presented here in a form wholly creditable to American science; there is no pretension about the volume; it assumes to be simply an account of the diversified vegetation of a single state, with respect to origin, distribution and adaptation. A sound sense of proportion and perspective characterizes the entire general survey thus given. With some of the minor matters we do not agree, but we accept freely the fact that the authors have acted according to their best judgment, and since they have investigated this disputed matter on the spot, we are inclined to give great weight to their decisions. The philosophic spirit and clear insight which mark the volume give it much value as an aid in the further prosecution of State botanical surveys. Since there is not a dull chapter in the whole treatise, it can be recommended to general students who may desire to see what new life has been infused into dry details of form and habitation of plants, and it will be accepted by botanists as a distinct and valuable contribution to ecology. G. L. G.

3. *A Text-book of Botany;* by Drs. Strasburger, Schimper, Noll and Schenck of the University of Bonn. Translated from the German by H. C. Porter, Ph.D., Assistant Instructor of Botany, University of Pennsylvania. London and New York, 1898. (The Macmillan Company.)—The German edition of this admirable work has been already reviewed in this Journal. Attention was then called to its excellence as an ideal text-book, and emphasis was laid on the clearness and succinctness with which the essentials of modern botany are presented in it.

We have now to notice the same work in an unexceptionable English dress. The translator has borne steadily in mind the maxim that an exact translation must make short work of idioms. In this case, the translator has broken up sentences into frag-

ments, and has consolidated fragmentary sentences, with a freedom which lends much charm to the whole work. Some of the English words chosen do not seem to us to be the most felicitous equivalents, but so far as a pretty careful search has gone, no misleading renderings have been observed. The authors may be congratulated on their choice of a translator who carries their useful work into a wider circle of students and general readers, and we extend our sincere congratulations to the translator for the success which he has attained in his work. G. L. G.

4. *Fossil Plants: for students of Botany and Geology;* by A. C. SEWARD, M.A., F.G.S., Lecturer in Botany in the University of Cambridge, vol. i, Cambridge, University Press. (N. Y., Macmillan, 1898.)—This work comes to us with a preface bearing the date March, 1898. The present volume consists of two parts: first, a general section, dealing with important generalia, and a second comprising the systematic treatment of certain fossil cryptogamia. The second volume promises to conclude the systematic treatment of plants, and then consider "such subjects as geological floras, plants as rock-builders, fossil plants and evolution, and other general questions connected with paleo-botany."

The historical sketch is very short and tantalizing. The author is critical and discriminating, and we should be glad to have his views as to the relative value of the works of some of the writers whom he dismisses with a mere mention. Chapter second, although very brief, brings out with great clearness some of the relations of paleobotany to botany and geology, and embodies a spirited protest against "the narrowness of view which too often characterizes paleobotanical literature." The next chapter treats of the successive strata, and is followed by an extremely interesting chapter on the preservation of plants as fossils. Then comes a frank statement of the difficulties and sources of error which environ the entire subject of determination of fossil plants. A whole chapter of the generalia is worthily devoted to a conservative statement of the vexed question of nomenclature and priority.

The systematic portion of the treatise secures confidence from the very start. Caution is shown at doubtful points, and the reader is at such places put properly on his guard, but where the pathway, although obscure, is safe, the author speaks boldly. Moreover, the style is attractive and the tone throughout is philosophical. We shall wait impatiently for the completion of the useful work. G. L. G.

5. *Contributions to Japanese Characeæ;* by T. F. ALLEN, LL.D.—In the midst of the cares incident to an exacting practice of the medical profession, Dr. Allen continues his fruitful studies of the Order Characeæ. The present work is on the same lines as his former valuable contributions, and exhibits independent treatment, especially in the demarcation of the limits of species. It is earnestly to be hoped that he will continue to derive recreation from researches which are of so much importance to botanists. G. L. G.

INDEX TO VOLUME V.*

A

Academy, National, report for 1897, 395; meeting at Washington, 396.
Actinometers, Electro-chemical, Rigollot, 228.
Agassiz, A., coral reefs of the Fiji group, 113.
Air waves, observation of, Emden, 70.
Alaska, gold fields, 305.
Alternating currents, change into direct, Graetz, 70.
American Microscopical Society, transactions, 321.
Ames, J. S., Manual of Experiments in Physics, 302.
Argentine, Paleozoic faunas, Kayser, 72.
Artesian wells in the Dakotas, Darton, 161.
Association, American, meeting at Boston, 397.
Astronomical Observatory, Harvard, Annual report, 80; Annals, 320.
Atoms in Space, Arrangement of, Van't Hoff, 388.
Auroral period, 27-day, Clayton, 81.
Austin, M., oxidation of manganese, 260; estimation of manganese, 209, 382.

B

Bailey, G. H., Tutorial Chemistry, 390.
Bailey, L. H., Lessons with Plants, 318.
Bain, H. F., limestone at Bethany, Missouri, 433.
Barringer, D. M., Minerals of Commercial Value, 155.
Barus, C., combination tones of siren and organ pipe, 88; electro-magnetic theory of light, 343.
Becker, G. F., Kant as a natural philosopher, 97; auriferous conglomerate of the Transvaal, 193; determination of plagioclase feldspars, 349.
Bigelow, F. H., solar and terrestrial magnetism, 455.
Bliss, W. J. A., Manual of Experiments in Physics, 302.
Bolometer, Langley, 241.
Bonney, T. G., origin of diamonds of South Africa, 76.
Botanical Works—
  Botany, Textbook, Strasburger, Schimper, Noll and Schenck, 471.
  Pflanzenphysiologie, Pfeffer, 317.
  Phytogeography of Nebraska, Pound and Clements, 471.
  Plants, Lessons with, Bailey, 318.
Botany—
  Cell-wall, structure of, Gardiner, 470.
  Cyperaceæ, No. vii, Holm, 47.
  Embryophyta siphonogama, Engler, 156.
  Flora of Franz Joseph Archipelago, Fisher, 236.
  Japanese Characeæ, Allen, 472.
  Permeability of the bark of tree trunks to atmospheric gases, Devaux, 318.
  Transpiration of plants, psychrometer for, Leavitt, 440.
British Museum Catalogues, 75, 319.
Burbank, J. E., X-rays and mineral phosphorescence, 53; phosphorescence by electrification, 55; source of X-rays, 129.

C

Calvin S., geology of Johnson Co., Iowa, 149.
Cathode rays, effect on air, Lenard, 149.
  See also *Röntgen rays* and *X-rays*.
Chalmers, R., pre-glacial decay of rocks in East. Canada, 273.
Chemical Works—
  Chemical Analysis, Manual of, Fleurent, 147.
  Preparations, Inorganic, Thorp, 222.

* This Index contains the general heads, Botany, Chemistry (incl. chem. physics), Geology, Minerals, Obituary, Rocks, and under each the titles of Articles referring thereto are mentioned.

CHEMICAL WORKS—
Chemistry, Analytical, 221; General, Ostwald, 222.
Organic, Noyes, 147.
Physical, Speyers, 390.
Tutorial, Bailey, 390.
CHEMISTRY—
Ammonium cyanide, manufacture of, Lance, 69.
Atmospheric air, influence of the silent discharge on, Shenstone and Evans, 464.
Borides of calcium, barium and strontium, Moissan and Williams, 388.
Carbon, conductivity for heat and electricity, Cellier, 223.
electro-chemical equivalent, Coehn, 218.
varieties of, Moissan, 220.
dioxide, action on soluble borates, Jones, 442.
Chlorine and hydrogen, action of light, Gautier and Hélier, 144.
Chromium tetroxide and perchromates, Wiede, 299.
Copper voltameter, Foerster, 219.
Electro-chemical method for changing currents, Graetz, 218.
Electrolytic decomposition of aqueous solutions, Nernst, 66.
dissociation and osmotic pressure, Traube, 463.
production of iodoform, Foerster and Meves, 466.
Fluorescence and chemical composition, Meyer, 387.
Gases, new methods for measuring, Bleier, 385.
Hydrogen, action on sulphuric acid, 465.
Hydrogen and oxygen, combination, Berthelot, 220; occlusion by palladium, 224.
cyanide, preparation, 465.
Iodine, method of preparing pure, 387.
Iron carbide, direct production, Moissan, 67.
Liquids, solubilities, Aignan and Dugas, 297.
Manganese, estimation of, Gooch and Austin, 209; Austin, 382.
oxidation of, Gooch and Austin, 260.
Osmotic pressure and electrolytic dissociation, Compton, 65.
Oxygen during reduction, evolution of, 298.
sulphur and selenium, series spectra, 145.
CHEMISTRY—
Peroxides, production of, Bach, 68.
Petroleum, formation of natural, Engler, 300.
Potassium percarbonate, Von Hansen, 299.
Refractivities of air, oxygen, etc., Ramsay and Travers, 227.
Rotation angle, new substance for increasing, Walden, 463.
Thermodynamics of the swelling of starch, Rodewald, 297.
Voltaic action, influence of proximity on, Gore, 144.
Chester, A. H., Catalogue of Minerals, 78; krennerite, from Cripple Creek, Colo., 375.
Clayton, H. H., 27-day auroral period and the moon, 81.
Collins, W. D., surface travel on electrolytes, 59.
Comets, orbits of, Stichenroth, 160.
Coral reef, see GEOLOGY.

D

Dana's Textbook of Geology, revised, Rice, 393.
Darton, N. H., geothermal data from artesian wells in the Dakotas, 161.
Dawson, J. W., genus Lepidophloios, 394.
DeLaunay, L., Diamants du Cap, 77.
Derby, O. A., accessory elements of itacolumite, etc., 187.
Diamonds, see MINERALOGY.
Dolbear, A. E., modes of motion, 148.
Durward, A., temperature coefficients of hard steel magnets, 245.

E

Electric arc, acoustic phenomena in, Simon, 302.
between aluminum electrodes, Lang, 149.
discharge in Geissler tubes, theory of stratification, Gill, 399.
in free air, Toepler, 149.
excitation, 302.
resistance standards, 391.
wind, Arrhenius, 148.
Electricity, production by chemical means, Andreas, 146.
Electrolytes, surface travel on, Fiske and Collins, 59.
Electromotive force, J. Trowbridge, 57.

F

Farrington, O. C., datolite from Guanajuato, 285.
Fiji Islands coral reefs, Agassiz, 113.
Fisher, H., flora of Franz Joseph Land, 236.
Fiske, W. E., surface travel on electrolytes, 59.
Fleurent, E., Manual of Chemical Analysis, 147.
Fluids, transparency for long heat ways, Rubens and Aschkinass, 391.
Fluorescence and actinic electricity, Schmidt, 467.
Foote, H. W., clinohedrite from Franklin, N. J., 289.
Franz Joseph Land, geology, 233; flora, Fisher, 236.
Funafuti, coral boring at, 75.

G

Gage, A., physical experiments, 222.
Geological nomenclature, 313.
Geological Reports and Surveys—
  Canada, vol. ix, 1896, 232.
  Georgia, 394.
  India, 394.
  Iowa, vol. vii, 1896, 152.
  New Jersey, 468.
  United States, recent publications, 303, 469.
  Witwatersrand, Southern Transvaal, Hatch, 393.
Geology, Dana's text-book, revised, Rice, 393.
Geology—
  Amphictis, skull of, Riggs, 257.
  Auriferous conglomerate of the Transvaal, Becker, 193.
  Bethany limestone, Missouri, Bain, 433.
  Coral boring at Funafuti, 75.
    reefs of the Fijis, 113.
  Cretaceous of Athabasca river, Tyrrell, 469.
    in Kansas, Gould, 169.
  Earth movement, Van Hise, 230.
  "Florencia formation," Pilsbry, 232.
  Fossil plants, Seward, 472.
  Geology of Franz Joseph Land, 233.
    of Johnson Co., Iowa, Calvin, 149.
  Geothermal data from artesian wells in the Dakotas, Darton, 161.
  Glyphioceras and phylogeny of the Glyphioceratidæ, Smith, 315.
Geology—
  Gold fields of Alaska, 305.
  Jurassic vertebrates from Wyoming, Knight, 186, 378.
  La face de la Terre, Suess, 152.
  Lava flows of the Sierra Nevada, Ransome, 355.
  Lepidophloios, Dawson, 394.
  Madreporarian corals in the British Museum, Bernard, 319.
  Massanutten Mountain, Virginia, geology, Spencer, 231.
  Paleozoic faunas of the Argentine, Kayser, 72.
  Petrography of the Boston Basin, White, 470.
  Pre-glacial decay of rocks in Eastern Canada, Chalmers, 273.
  Protostegan plastron, Wieland, 15.
  See also Rocks.
Georgia geol. survey, 394.
Geyser eruption, conditions affecting, Jaggar, 323.
Gill, H. V., stratification of electric discharge in Geissler tubes, 399.
Goldschmidt, V., Krystallographische Winkeltabellen, 153.
Gooch, F. A., estimation of manganese, 209; oxidation of manganese, 260.
Goode, G. B., History of the Smithsonian Institution, 158.
Gould, C. N., transition beds from the Comanche to the Dakota Cretaceous, 169.
Groth, P., mineralogical tables, 154.
Guthe, K. E., measurement of self-inductance, 141.

H

Harmonic analyzer, new, Michelson and Stratton, 1.
Haswell, W. A., Text-book of Zoology, 319.
Headden, W. P., tin compounds from an old furnace in Cornwall, 93.
Heat conductivity, relative, Voigt, 223.
Hidden, W. E., rhodolite, 294.
Hintze, C., Handbuch der Mineralogie, 316.
Hoffmann, G. C., xenotime in Canada, 235.
Holm, T., studies in the Cyperaceæ, No. vii, 47.
Howe, J. L., Bibliography of Platinum Metals, 322.

I

India geol. survey, 394.
Iowa, Johnson Co., geology, Calvin, 149.

J

Jagger, T. A., Jr., conditions affecting geyser eruption, 323.
Johanniskäfer light, Muruoka, 224.
Jones, L. C., action of carbon dioxide on soluble borates, 442.

K

Kant as a natural philosopher, Becker, 97.
Kayser, E., Paleozoic faunas of the Argentine, 72.
Kleinasiens Naturschätze, Kannenberg, 79.
Knight, W. C., Jurassic vertebrates from Wyoming, 186, 378.
Knipp, C. T., new form of make and break, 283.

L

Lacroix, A., Mineralogy of France, 155.
Langley, S. P., the bolometer, 241.
Leavitt, R. G., psychrometer for study of transpiration, 440.
Light, electro-magnetic theory, Barus, 343.
  Visible and Invisible, Thompson, 71.
Lindren, W., orthoclase as gangue mineral, 418.
Lockyer, N., Sun's Place in Nature, 300.

M

Magnetism, determination of, Meyer, 467.
  solar and terrestrial, Bigelow, 455.
Magnets, properties of seasoned, Pierce, 334.
  temperature coefficients of, Durward, 245.
Make and break, new form, Knipp, 283.
Marsh, O. C., Cuvier prize awarded, 79; collections presented to Yale University, 156.
Mazama, Crater Lake number, 79.
Mechanics, applied, Perry, 80.
Meteoric iron, San Angelo, Texas, Preston, 269.
  from Australia, Ward, 135.
  structure and origin, Preston, 62.
  stone, Jerome, Kansas, Washington, 447.
Mexico, bulletin of geological institute, Aguilera, 152.
Michelson, A. A., new harmonic analyzer, 1; spectroscope without prisms or gratings, 215.
Millikan, R. H., general physics, 389.
Mineral resources of the U. S. for 1896, 469.
Mineralogica, Synopsis, Weisbach, 78.
Mineralogical tables, Groth, 154.
Mineralogie, Handbuch der, Hintze, 316.
Mineralogy of France, Lacroix, 155.
Minerals, catalogue of, Chester, 78; Foote, 155.
  of commercial value, Barringer, 155.
Minerals—
  Albite, etching-figures, 182.
  Anorthite, No. Carolina, 128.
  Anthophyllite, No. Carolina, 429.
  Axinite, etching-figures, 180.
  Berthierite, Calif., 428.
  Beryl, No. Carolina, 432.
  Bronzite, Jackson Co., N. C., 431.
  Cassiterite, etc., from tin furnace, 93.
  Chalcanthite, etching-figures, 182.
  Clinohedrite, Franklin, N. J., 289.
  Cyanite, No. Carolina, 126; etching-figures, 181.
  Datolite, Mexico, 285.
  Diamond, artificial production, 469.
  Diamonds of South Africa, origin of, Bonney, 76; work on, De Launay, 77; artificial, 469.
  Enstatite, No. Carolina, 430.
  Feldspars, plagioclase, determination of, 349.
  Gersbyite, Sweden, 316.
  Gold, crystalline structure of nuggets, 235.
  Gold ores containing tellurium, selenium and nickel, 427.
  Graphite, graphitite and graphitoid, 146.
  Krennerite, Colorado, 375.
  Langbeinite, 316.
  Leonite, 316.
  Molybdenite, Calif., 426.
  Orthoclase as gangue mineral, 418.
  Raspite, 315.
  Rhodolite, 294.
  Rhodonite, etching-figures, 182.

MINERALS—
Tourmaline, etching-figures, 178; secondary enlargement, 187.
Tripuhyite, Brazil, 316.
Xenotime, Ontario, 235.
Zircon, No. Carolina, 127; Calif., 426.
Zirkelite, 153.
Mississippi river, floods, 240.
Missouri Botanical Garden, 8th annual report, 78.

N

Nebraska, Phytogeography of, Pound and Clements, 471.
New Jersey, physical geography, Salisbury, 468.
Nipher, F. E., measurement of pressure of wind, 468.
Noyes, W. A., Organic Chemistry, 147.

O

OBITUARY—
Haughton, S., 80.
Marcou, J., 398.
Rogers, W. A., 322.
Schrauf, A., 160.
Winnecke, Prof., 80.
Ostwald, W., Works on Chemistry, 221, 222.
Ostwald's Klassiker der exakten Wissenschaften, 80.

P

Parker, T. J., Text-book of Zoology, 319.
Peirce, B. O., properties of seasoned magnets, 334.
Pendulum, new form, Stevens, 14.
Penfield, S. L., clinohedrite from Franklin, N. J., 289.
Pennsylvania, Brownstones of, Hopkins, 78.
Perry, J., Applied Mechanics, 80.
Petrology for students, Harker, 317.
Pfeffer, W., Pflanzenphysiologie, 317.
Phosphorescence produced by X-rays, Burbank, 54; by electrification, Trowbridge and Burbank, 55.
Physical Experiments, Gage, 222.
Physics, Deductive, Rogers, 148.
Experiments in General, Stratton and Millikan, 389.
Manual of Experiments in, Ames and Bliss, 302.
Stone, 222.
Physikalisch-chemische Propädeutik, Griesbach, 321.
Pilsbry, H. A., "Florencia formation," 232.
Pratt, J. H., mineralogical notes from North Carolina, 126, 429; rhodolite, 294.
Preston, H. L., San Angelo meteorite, 269; iron meteorites, structure and origin, 62.
Prinz, geological experiments, 392.
Psychrometer, Leavitt, 440.

R

Radiant heat, transmission by gases, Brush, 222.
Ransome, F. L., lava flows of the Sierra Nevada, 355.
Rayleigh, nature of the X-rays, 467.
Rice, W. N., Dana's Textbook of Geology, revised, 393.
Riggs, E. S., skull of Amphictis, 257.
ROCKS—
Amphibole-pyroxene rock, Calif., 423.
Diorite, Calif., 422.
Granitic breccias of the Cripple Creek region, Stone, 21.
Itacolumite, accessory elements of, Derby, 187.
Latite, Sierra Nevada, Ransome, 355.
Quartz-alunite rock, Calif., 424.
Quartz-amphibole-diorite, Calif., 421.
Rogers, F. J., Deductive Physics, 148.
Röntgen radiation, influence on combination of ions, Rutherford, 386.
Röntgen rays, heat produced by, Dorn, 148.
nature of, Stokes, 301.
original papers on, Röntgen, 223.
and ordinary light, Rayleigh, 467.
see also *X-rays*.
Rubens, H., absorption of infra-red rays by rock salt and sylvine, 33.
Russell, I. C., Volcanoes of North America, 74.

S

Salisbury, Physical Geography of New Jersey, 468.
Science abstracts, 398.
Self-inductance, measurement of, Guthe, 141.
Seward, A. C., Fossil Plants, 472.
Shunt box, Stine, 124.

Siren and organ pipe, combination tones of, Barus, 88.
Smithsonian Institution, History, Goode, 158; report, Langley, 239.
Spectroscope, new form, Michelson, 215.
Spectroscopic Tables, Engelmann, 72.
Spectrum, infra-red, Rubens and Aschkinass, 391.
absorption by rock salt and sylvine, Rubens and Trowbridge, 33.
Speyers, C. L., Physical Chemistry, 390.
Stevens, J. S., new form of pendulum, 14.
Stine, W. M., simple compensated shunt box, 124.
Stone, G. H., granitic breccias of the Cripple Creek region, 21.
Stone, W. A., Physics, 222.
Stratton, S. W., new harmonic analyzer, 1; Experiments in Physics, 389.
Suess, E., La face de la terre, 152.
Sun's Place in Nature, Lockyer, 300.
Sylvester medal, 240.

T

Thompson, S. P., Light, visible and invisible, 71.
Thorp, F. H., Inorganic Chemical Preparations, 222.
Transvaal, auriferous conglomerate of, Becker, 193; geological survey, Hatch, 393.
Trowbridge, A., absorption of infra-red rays in rock salt and sylvine, 33.
Trowbridge, J., phosphorescence produced by electrification, 55; electromotive force, 57; source of X-rays, 129.
Turner, H. W., rocks and minerals from California, 421.
Tyrrell, Cretaceous of Athabasca river, 469.

U

United States Coast Survey, 320.
Geol. Survey, recent publications, 303.

V

Van Hise, C. R., earth movement, 230.
Van't Hoff, Arrangement of Atoms in space, 388.
Vibration time of high notes, 302.
Volcanoes of North America, Russell, 74.

W

Wadsworth, M. E., zirkelite, 153.
Walker, T. L., etching figures on triclinic minerals, 176.
Ward, H. A., Australian meteorites, 135.
Washington, H. S., Jerome, Kansas, meteorite, 447.
Weisbach, Synopsis Mineralogica, 78.
White, T. G., petrography of the Boston Basin, 470.
Wieland, G. R., the protostegan plastron, 15.
Wind pressure measured, Nipher, 468.

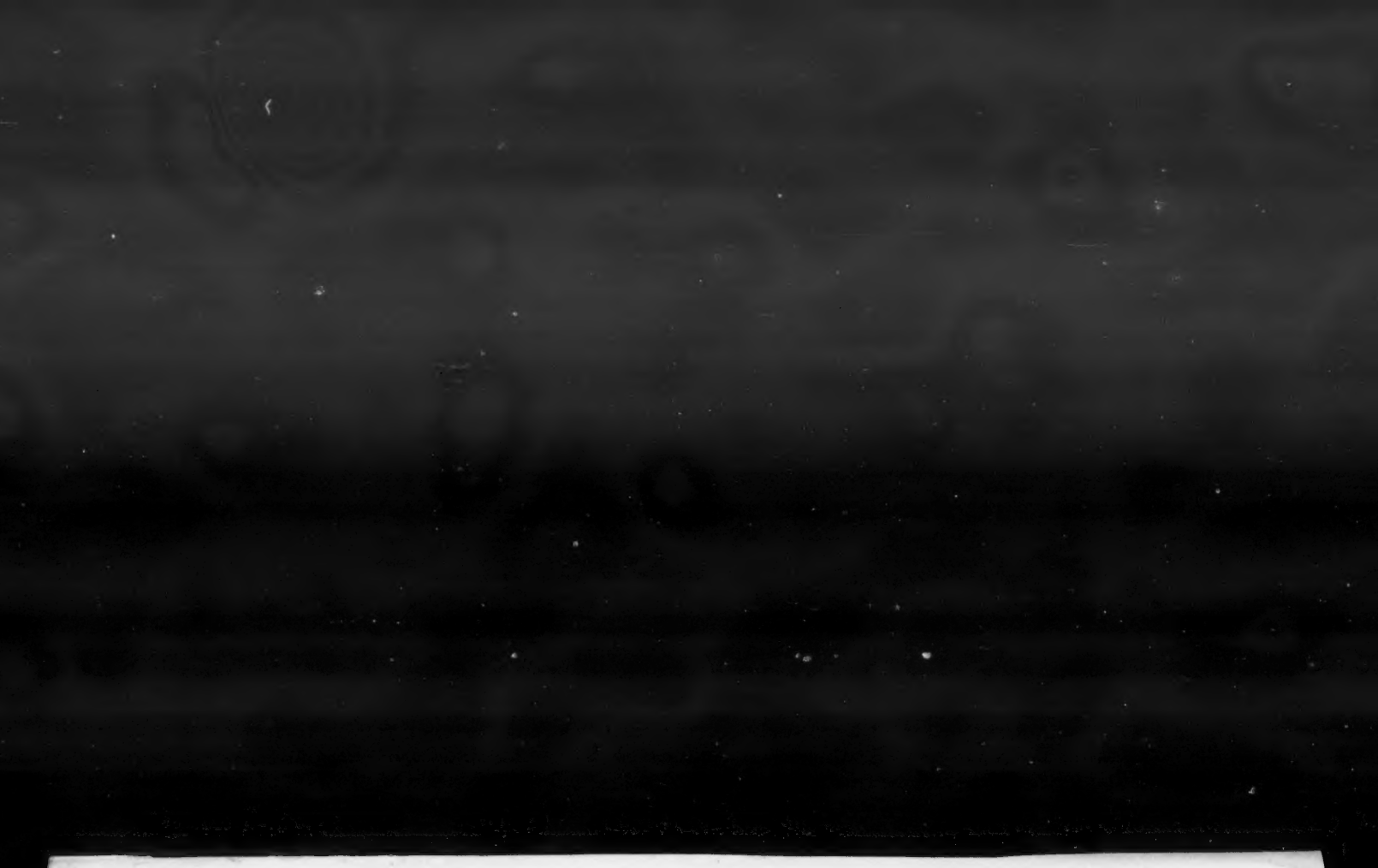
X

X-rays, impulse theory, Thomson, 301.
literature, bibliography, Phillips, 71.
source of, Trowbridge and Burbank, 129.
and mineral phosphorescence, Burbank, 53.
See also *Röntgen Rays.*

Z

Zoology, international congress, 1898, 238.
text-book, Parker and Haswell, 319.

ERRATA TO THE MARCH NUMBER.

p. 191, line 17 from bottom, after *mineral*, add *with zircon.*

p. 192, line 6 from top, for *magnètic* read *magmatic.*